



University of Pretoria
SENTECH Chair Report 2006-2008

100
1908 - 2008



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Engineering, Built Environment and
Information Technology



Sentech Chair in Broadband Wireless Multimedia Communications (BWMC)
Department of Electrical, Electronic and Computer Engineering



Broadband Wireless - THRIP

Maharaj BTJ

Income and expenditure report for the period 1 January 2007 to 30 December 2007

Income	707,990
Income – Grant	707,990
Expenditure	566,046
Salaries	43,179
Conferences	12,626
Stationery	3,153
Travelling	6,889
Refreshments	4,380
Lab equipment	67,791
Computer equipment	15,112
Audiovisual equipment	13,618
Equipment in process	2,822
Internet	180
Computer software	97,436
Bursaries	232,124
Books and DVDs	793
University overheads	65,740
Sundry expenses	204
Surplus / (deficit) for the period	141,944
Surplus / (deficit) at the beginning of the period	
Surplus / (deficit) at the end of the period	141,944

The report is compiled in accordance with the books of the University of Pretoria

[Signature]
Director of Finance

Date 2008-03-17

Direkteur van Finansies
Director of Finance
Molaodi wa Ditshilete
UNIVERSITEIT VAN
UNIVERSITY OF
YUNIBESITHIYA
PRETORIA

Contents

Foreword: SENTECH COO	4
Vision: Dean	5
Strategy: Head of Department, Electrical, Electronic and Computer Engineering	6
Message: Acting SENTECH Chair in BWMC	7
Mission	8
Vision	8
Facilities	9
Staff	9
Students	10
Partners	12
Research and Development Activities	13
International Collaboration / Partnerships	14
Student Projects and Research	16
Research Summary: K A Ruder	21
Research Summary: D Sokoya	22
Research Summary: K P Maré	23
Research Summary: L Nair	24
Publications	25
Financial	29



Mrs Bev Ngwenya
Chief Operating
Officer

Foreword: SENTECH COO

SENTECH is the largest broadcasting signal distributor in Africa. The SENTECH tower in Brixton is a spectacular icon carrying 108 different signals – more signals than any other high site in Africa.

We maintain a network of 220 transmission stations that distributes the broadcasting signals for the SABC, e.tv, Multichoice and a variety of radio stations from the very large to those operating at community level. Our extensive experience in broadcasting signal distribution is recognised as superior throughout the African continent and internationally.

Digital Terrestrial Television (DTT) is a key project within the broader objective of establishing an information society. The digitisation of the television terrestrial network will ensure increasing access, with the licensing of more channels that should offer programming in more official languages and also cover cultural diversity issues; deliver information quicker and therefore foster greater participation. SENTECH is gearing up for the 1 November 2008 switch-on date.

In our continuing effort to create, build knowledge and discover the full potential of how broadband can improve the quality of life for ordinary South Africans by building an information society, SENTECH continues to sponsor the Chair in Broadband Wireless Multimedia Communications (BWMC) at the University of Pretoria.

The main aim of the BWMC is to promote relevant research of wireless broadband technologies and its practical application in a developing country. Furthermore, it endeavours to support the objectives of JIPSA (Joint Initiative on Priority Skills Acquisition), especially with the country's current engineering skills shortage, particularly in the field of wireless technology.

This initiative is in its third year with eighteen students (bursary and research students) enrolled this year, of whom ten are postgraduate; the initiative is undoubtedly going from strength to strength. SENTECH is proud to say that one of 2006's successful students has already joined SENTECH on a permanent basis.

The three-year research activities of the Chair encompass two major categories, which are also in line with international trends: multimedia applications and services (high data-rate type development); and multiple-input-multiple-output (MIMO) technology.

In the case of multimedia application research, it is anticipated that the need for Internet access, real-time conferencing, voice, telemedicine and tele-education will grow. Furthermore, last-mile broadband access for residential, SMMEs, business, schools, clinics, etc. is becoming a major requirement in Africa and other developing countries.

SENTECH brings to the market a wide range of telecommunication and information services for consumer, corporate and various business applications. Importantly, with this partnership SENTECH hopes to further the interaction between academic institutions and industry as well as promote SENTECH next-generation technology.

Vision: Dean

The University of Pretoria and in particular its School of Engineering strives to be a leading source of top-class engineers and research contributions and has indeed achieved much in this regard, especially in the fields of electronic and computer engineering. The success and sustainability of teaching and research programmes in engineering, and especially in fast-developing fields such as wireless communications, are significantly enhanced through close cooperation. This is possible with the support of leading-edge industrial partners such as: SENTECH, SENTECH CHAIR IN BROADBAND WIRELESS MULTIMEDIA COMMUNICATIONS (BWMC) and the Department of Electric, Electronic and Computer Engineering at the University of Pretoria.

Since its founding in 2005, the SENTECH Chair has already enabled us to attract top-class staff and students to BWMC activities, to better equip our laboratories and to establish ourselves internationally. We are indeed privileged to partner with SENTECH in this very important field and are looking forward to the further development of this relationship.



Prof RF Sandenbergh
Dean





Prof FW Leuschner
Head of Department

Strategy: Head of Department, Electrical, Electronic and Computer Engineering

The SENTECH Chair in Broadband Wireless Mobile Communications (BWMC) celebrates three years in operation since its inception at the University of Pretoria. This Chair has consistently strived to deliver engineers and do research (fundamental and applied) – the focus of the Department of Electrical, Electronic and Computer Engineering (DEECE).

The Department and SENTECH Chair's challenge for the future will be to deliver the right engineers for the needs of South Africa. This will require focus on the degree programme curricula of all three disciplines, transformation so as to represent all groups and genders in the country in the right proportion, and enable lecturers and students that are excited about their careers and take control of their future.

This challenge started with the new curriculum 2008, which started in 2008 with the new first-year intake, and has been part of the SENTECH Chair mission and objectives from inception.

A second focus of the Department is to conduct basic and applied research in the appropriate fields that are essential to the prosperity of the country. Lecturers in the Department are encouraged to undertake research in their fields of specialisation and to test their research through the process of peer evaluation by participating in conference presentations and published journal articles. Lecturers are encouraged to participate in contract research and consultation to assure that application of their subject knowledge is available for all interested parties in the country and abroad. The SENTECH Chair has excelled in this area with articles in accredited journals and publication research outputs in peer-reviewed international conference proceedings.

A large department such as ours cannot function properly unless structures are in place to support lecturers and students to fulfil their commitment to education (delivering and receiving), unless a well-organized administrative structure is in place and every person understands her/his leadership role in the organization.

Excellent world-class laboratories and equipment is essential for fast-changing technologies, such as those practised by lecturers and students in our Department. Support staff at all levels must take part in the education and research activities of the Department.

The Department Head's challenge is to enable everybody in the Department to live their dream and remove or reduce all obstacles that they may encounter in achieving their goals. The Chair, staff and students at the SENTECH Chair took up this challenge right from the start, and delivered much more than anticipated. Already, the Chair collaborates with cutting-edge researchers and institutions all over the world to enhance the international competitiveness of our Department.

Message: Acting SENTECH Chair in BWMC

The SENTECH Chair in Broadband Wireless Multimedia Communications (BWMC) was officially founded on 12 July 2005 and came into effect in 2006. Since assuming the acting position in April 2006, we strove to build the Chair into a world-class research facility. The student intake grew from five bursars in the first year to a total of 18 students (including final-year design project, masters and PhD students) in 2008.

“Life is like riding a bicycle. To keep your balance you must keep moving.”

In keeping with the above Einstein ethos, we have endeavoured to “keep on moving” with the support of all our partners, viz. SENTECH, DTI, NRF, students, researchers, administrative support and management. Having started this facility from ‘Greenfield’, it has been a challenge with great opportunity to develop the laboratories, student research facilities and a unique branding for this Chair. Much acknowledgement must be given to Dr P Rademeyer who has been with SENTECH Ltd. and the administrative support of Ms Lynette van den Heever and her predecessor Ms Sharon Mashau, thanks to whom we now have two equipped project and research laboratories, six postgraduate rooms and a seminar room, making it a very conducive environment for challenging the intellect so as to develop innovative ideas and outputs.

Like Mahatma Gandhi said:

“All research will be useless if it is not allied to internal research.”

We aspire to realize the full potential of our students through their focussed interests and commitment. Our research area has been largely focussed on Broadband Wireless Communications and specifically on MIMO technology and OFDM systems. Through the financial support of SENTECH Ltd and the Department of Trade and Industry’s (DTI) THRIP-programme, we have been successful in recruiting students with high work ethic and great ambition. This has enabled us to make good progress in terms of student participation rate and publications over this short period, and hence see tangible outputs with our first batch of master’s students either graduating or completing their degrees in 2008.

The purpose of this report is three-fold:

1. To provide an overview of the development and progress of the SENTECH Chair in Broadband Wireless Multimedia Communications
2. To introduce the research activities, levels of expertise and achievements
3. To highlight the team members and their goals attained during the past two and a half years.

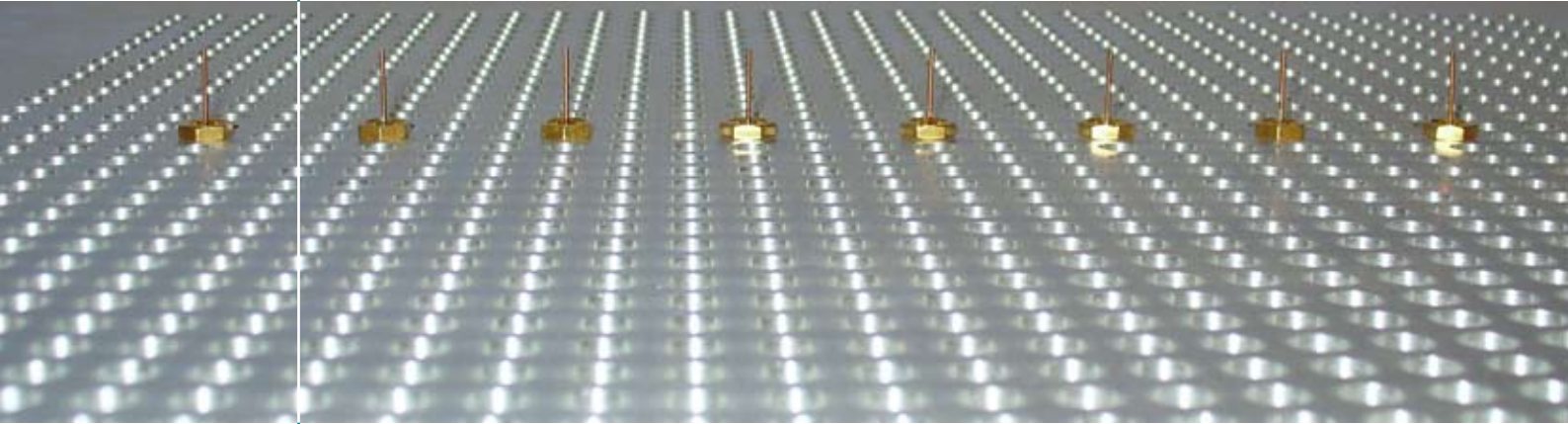
It is our desire that through this publication the reader will gain insight into the SENTECH BWMC activities, its vision and opportunities for growth, involvement and collaboration.



Dr Sunil (BTJ) Maharaj

Mission

The mission of the SENTECH BWMC Chair is to participate in forefront research activities in the field of broadband wireless multimedia communications and to deliver world-class research and educational outputs for the benefit of SENTECH, the University and South Africa in general.



Vision

The Chair in BWMC:

- Promotes study and research in the field of broadband wireless multimedia communication networks, products and services
- Collaborates on SENTECH's related products
- Furthers the interaction between academic institutions and the industry in general and specifically between UP and SENTECH
- Furthers education and teaching specifically in the fields of RF communications, digital transmission technology, digital network technology and telecommunication on an undergraduate and postgraduate level in unison with the research and product development efforts of the BWMC Chair
- Develops high-quality technical skills and expertise for industry and the research fraternity
- Produces outputs such as masters and doctoral research, high-quality publications, prototypes and products
- Addresses the historical imbalances of the past and women in engineering innovation
- Contributes to the global competitiveness of Africa and South Africa in particular.

Facilities

The BWMC facilities were available from October 2006 and they are situated in Engineering Sciences Building 2 on the 2nd floor. There is a fully-functioning seminar room for meetings, seminars and professional development short courses, a wireless research and an innovation lab.

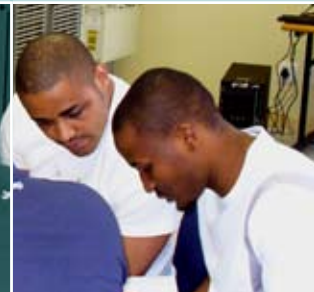
The current floor space availability is as follows:

Office for the Chair	2-13
Office for Administrator	2-15
Postgraduate Student Offices	2-12, 14, 17, 19, 21, 22
Seminar Room	2-20
SENTECH Innovation Lab (design projects)	2-7
Wireless Research Lab	2-8



Staff

The SENTECH BWMC staff comprises the Chair, Dr BTJ. Maharaj, Administrator, Mrs L van den Heever and postgraduate (hons, masters and PhD candidates) and undergraduate students.



Students

Since the inception of the SENTECH Chair on 12 July 2005, the following students have participated in the SENTECH BWMC research group:

2006 Students

NAME	YEAR OF STUDY in 2006
Lakshmi Nair	MEng (Computer Engineering)
Bobby Varghese	MSc (Applied Science)
Karel-Petrus Maré	BEng Hons (Electronic Engineering)
Kamal Ruder	BEng Hons (Technology Management)
Bongani Manitoba	BEng (Electronic Engineering) 4
Jacques Groenewald	BEng (Electronic Engineering) 4
Irvin Simelane	BEng (Electrical Engineering) 4
Patrick Ngwenyama	BEng (Electronic Engineering) 4
Christo Kleu	BEng (Computer Engineering) 3
Hannetjie Nell	BEng (Electronic Engineering) 2

2007 Students

NAME	YEAR OF STUDY in 2007
Dare Sokoya	PhD (Electronic Engineering)
Kamal Ruder	MEng (Technology Management)
Brian Salmon	MEng (Electronic Engineering)
Lakshmi Nair	MEng (Computer Engineering)
Karel-Petrus Maré	MEng (Electronic Engineering)
Daniel Basilio	BEng Hons (Electronic Engineering)
Philip Botha	BEng (Computer Engineering) 4
Christo Kleu	BEng (Electronic Engineering) 4
Christo Lötter	BEng (Electronic Engineering) 4
Francios Luus	BEng (Electronic Engineering) 4
Gerhard Wagner	BEng (Electronic Engineering) 4
Lawrence Zimba	BEng (Electronic Engineering) 4
Hannetjie Nell	BEng (Electronic Engineering) 3

2008 Students

NAME	YEAR OF STUDY in 2008
Kahesh Dhuness	PhD (Electronic Engineering)
Dare Sokoya	PhD (Electronic Engineering)
Lakshmi Nair	MEng (Computer Engineering)
Philip Botha	MEng (Electronic Engineering)
Karel-Petrus Maré	MEng (Electronic Engineering)
Daniel Basilio	MEng (Electronic Engineering)
Danie Louw	MEng (Electronic Engineering)
Kgomotso Sethlapelo	BEng Hons (Electronic Engineering)
Francios Luus	BEng Hons (Computer Engineering)
Lawrence Zimba	BEng Hons (Electronic Engineering)
Simon Barnes	BEng (Electronic Engineering) 4
Hannetjie Nell	BEng (Electronic Engineering) 4
Thinus Prinsloo	BEng (Electronic Engineering) 4
Glen Stein	BEng (Electronic Engineering) 4
Willie van der Merwe	BEng (Computer Engineering) 4
Johan van Rooyen	BEng (Electronic Engineering) 4
Richard van Schalkwyk	BEng (Computer Engineering) 3
Adriaan Struwig	BEng (Computer Engineering) 2

Overview of student growth

Year	BEng	BEng (Hons)	MEng	PhD	TOTAL headcount
2006	6	2	1		9
2007	6	2	4	1	13
2008	8	3	5	2	18

Racial and gender profile

Year	White male	Black male	Black female	White female	Total
2006	3	4	1	1	9
2007	8	3	1	1	13
2008	11	5	1	1	18

Partners

The DTI THRIP Programme

We have been fortunate to be supported by the Department of Trade and Industry, Technology and Human Resources Investment Programme (THRIP) which is administered by the National Research Foundation (NRF). Since our first application in 2005, we have received funding for each of the subsequent years of application. This funding has made a significant contribution to the research activities of the BWMC group in that we attracted more students through bursaries than initially envisaged and also purchased some equipment for students to use in their laboratory experimentation and projects.

SENZO IT

SENZO IT is a BEE SMME and has been partnering in the SENTECH BWMC activities from 2007. SENZO IT is one of SENTECH's business partners – hence this relationship is a logical and appropriate one. SENZO IT benefits from the knowledge and expertise that resides in the research group and empowers them in technical decisions and strategic positioning of their business.



NATIONAL RESEARCH FOUNDATION



the dti

Department:
Trade and Industry
REPUBLIC OF SOUTH AFRICA

Research and Development Activities

The SENTECH Chair promotes study and research in the field of broadband wireless multimedia communications technology and services. It furthers interaction between the University of Pretoria and industry (SENTECH and SENZO IT) which is mutually beneficial. Education and training, innovative results and processes, novel techniques and products in the field of Radio Frequency (RF) communications and Digital Signal Processing are developed.

Research areas that enhance business include:

- RF transmission and penetration
- Modelling
- RF planning and
- Wireless access technologies.

Efficient data transmission and high throughput using existing, but improved and new technology like MIMO systems and OFDMA contributes to this realization.

The interdisciplinary nature of the research requires a wide range of skills for software developers, hardware designers and signal processing. Thus, this initiative will also enhance collaboration between different skills bases and create an environment that will train people to communicate, adapt and work in a multicultural environment.

The main thrust of the research is channel modelling and space-time processing in multiple-input-multiple-output (MIMO) technology, to exploit the inherent advantages this affords in high data rates (throughputs) communications without necessarily increasing the channel bandwidth and power radically. We are collaborating with a group of widely-published international experts in this area from Brigham Young University, UTAH, USA, and are developing a relationship with other institutions in Germany (Jacobs University, Bremen and Technical University of Ilmenau, through SENTECH) so as to become globally competitive and give our researchers international exposure and networks.

We are also involved in WiMAX project work and technology development. This benefits SENTECH, as their strategy is to embark on such or similar technology for broadband multimedia communications. Our work encompasses algorithm development and testing, as well as the development of a WiMAX simulator where we incorporate different models (i.e. existing and our own unique models) and undertake performance analysis.

Thirdly, we are investigating the technology and development of a prototype for SENTECH broadcasting – a Digital Receiver Mondiale (DRM receiver), which we will be unique for the African market.

In 2005/6 there was no published research on MIMO channel modelling for the indoor, industrial or outdoor-type environment in Africa or South Africa for that matter. Our research efforts have been seminal work for African developing countries and the models could be useful. Our published work on MIMO frequency scaling for the 2-6 GHz band in indoor environment was unique and well received internationally. The results we provide should benefit telecommunications systems and be used by those that are involved in wireless network planning and optimization.

High data-rate type services in a fixed-wireless and more specifically in the mobile type environment, is still in its infancy and will be increasing in South Africa and the rest of the world. This will mainly be due to the WiMAX and UMTS- deployment. Our research work on channel modelling and space-time coding will contribute to this pool of knowledge and will also develop highly-skilled graduates that would add value to the competitiveness of the South African industry.



International Collaboration / Partnerships

We have been working with the following persons and some have been Visiting Scientists or Professors in the BWMC group:



PROF MICHAEL A JENSEN

Department of Electrical and Computer Engineering
Brigham Young University
Provo, UT 84602, UTAH, USA.



PROF JON W WALLACE

School of Engineering and Science
Jacobs University (formerly International University of Bremen (IUB))
Bremen, D-28759, Germany.



PROF CHENGSHAN XIAO

Department of Electrical and Computer Engineering
University of Missouri-Rolla
229 EECH, Rolla, MO 65409
USA

Prof Xiao was Visiting Professor within the SENTECH Chair in Broadband Wireless Multimedia Communications at the University of Pretoria in 2006 and he presented two seminars on Wireless MIMO Communications over Triply Selective Fading Channels.



PROF KHALED B LETAIEF

Head: Department of Electrical and Computer Engineering
Hong Kong University of Science and Technology
Clear Water Bay, Kowloon, Hong Kong

Prof Letaief visited our group in February 2007 and he presented two seminars in the area of Trends and Challenges for the Next Generation Broadband Wireless Networks. One seminar was held in conjunction with the South African Institute of Electrical Engineers and the IEEE SA Chapter in Communications and Signal Processing.



PROF VIJAY K BHARGAVA

Head: Department of Electrical and Computer Engineering
University of British Columbia
Vancouver, BC Canada V6T 1Z4

Prof Bhargava was hosted as a Visiting Professor in September 2007 and he presented seminars on Research Issues in Cognitive Radio Networks and Reed-Solomon Coding Techniques and Opportunities.



*Prof Jensen, Prof Wallace, Dr Maharaj at
BYU University (Utah) Wireless Lab*



*Dr Rademeyer, Prof Xiao, and
Mr Botes at SENTECH*



*Mr Botes, Prof Letaief, Dr Maharaj, Mr Conradie
and Mr Bester at SENTECH Seminar*

Student Projects and Research



**A FPGA Based MIMO
Synchronization System**

Jacques Groenewald
BEng



**Design and Implementation
of an Electronically Tuneable
Image Reject RF Filter for
Software-Defined Radio**

Patrick Ngwenyama
BEng



**Automated Money
Identification System
in Fixed Networks**

Bongani Matoba *BEng*



**Decoding the Information
Channels of a Digital Radio
Mondiale Signal**

Christo Kleu
BEng



**Fountain Codes for Universal
Data Compression**

Francois Luus
BEng Hons ('08)



**Design and Implementation
of the WiMAX Physical Layer**

Lawrence Zimba
BEng Hons ('08)

Propagation Modelling for Universal Mobile Telecommunications System (UMTS) Networks in an Urban Environment



Gerhard Wagner
BEng

A Technology Selection Framework for the Telecommunications Industry in Developing Countries Using the Example of WiMAX and UMTS

The objective of this study was to develop a new technology selection model that can be added to the pool of existing selection models. The new model can be used by the telecommunications service providers in developing countries for choosing new technologies that will best suit the company and the country. The model will be demonstrated by applying it to the example of WiMAX and UMTS.



Kamal Ruder
MEng

LDPC Space-Time Codes for MIMO Multipath-Fading Channels

Karel-P is developing a suitable MIMO channel model that simulates realistic mobile wireless channels. This channel will consist of:

- Frequency-selective fading
- Time-non selective fading (known as fast and slow fading)
- Space-selective fading (spatially correlated & uncorrelated conditions).

The MIMO channel model will be combined with the WiMAX platform created by Brian Salmon (SENTECH MEng student) to evaluate the performance of WiMAX in MIMO-conditions. Further improvements to the channel will be investigated by combining low-density parity check (LDPC) codes with space-time codes (STC) to exploit the spatial diversity, time diversity, as well as frequency selective fading diversity. The results obtained will illustrate the effects of MIMO WiMAX systems, as well as the effect of combining LDPC codes with STC under these conditions.



Karel-Peet Maré
MEng



Danie Louw
MEng

Non-Binary Error Control Codes in a MIMO Based Communication System

Danie is researching the application of non-binary error-control codes to a MIMO based communication system. The most important coding class to be considered is non-binary LDPC coding over finite fields and rings. The effect of different construction methods, different decoding algorithms as well as different mappings to modulation symbols will be considered. Algebraic design methods have great potential for improving the design of short-to medium-frame length LDPC codes and will thus also be studied. The use of non-binary codes will allow for a complete symbol-based communication system where the coding symbols are matched to either space-time-coded symbols, space-frequency-coded symbols or space-time-frequency coded symbols, depending on the system. At the receiver an iterative, turbo-like, joint receiver and decoder structure would be employed. The channel model and simulator developed in the SENTECH BWMC group will be used in this research work.



Philip Botha
MEng

Multiple-Input-Multiple-Output (MIMO) System Equalisation

Philip is researching the problem of Multiple-Input-Multiple-Output (MIMO) system equalisation. The research includes the problem of channel estimation between the antenna arrays or users in the presence of frequency-selective fading.

Specifically, the suitability of Support Vector Machines (SVM) and neural networks such as the Hopfield and Tank Neural Network to the problem of channel estimation and equalization is being investigated. The emphasis with the neural networks currently is on Multi-user Detection in the event that the number of users exceeds the number of receive antennas, resulting in a rank-deficient situation. It is anticipated that multipath diversity can be used to overcome this situation.



Lakshmi Nair
MEng

Industrial Wideband MIMO Channel Characterisation

The project investigates the effect of the industrial environment on the MIMO channel. Lakshmi uses data obtained from a measurement campaign done at the University of Pretoria in the Heavy Machinery Lab. An 8x8 MIMO system was employed using linear dual-polarised patch arrays and measurements were taken at 2.4 and 5.2 GHz. Various statistics will be determined and the data will be fitted to various models proposed in literature, to characterize the MIMO channel. Comparison between some of the channel statistics at 2.4 and 5.2 GHz will also be made to determine the effect of frequency scaling. During research, measured data will be fitted to the following models:

- i.i.d Gaussian model
- Kronecker product model
- A stochastic-geometry model similar to that proposed by Bonek, et al.

Alleviating Joint Lattice Decoding Complexity of Space-Time-Frequency Block Codes in MIMO-OFDM (MIMO WIMAX) Systems

Space-time-frequency block codes (recently proposed for MIMO-OFDM systems), achieve full rate (Mt) and full diversity ($Mt*Mr*L*Mb$) in space, frequency and time. My research is currently focuses on alleviating the joint lattice decoding complexity of space-time-frequency block codes in MIMO-OFDM (MIMO-WiMAX) systems, by using various filtered and un-filtered ZCZ CDMA sequence families, on a triply selective MIMO channel (developed by K.P. Maré). The CDMA will be incorporated either by using direct spreading or convolutional spreading. The type of system structure is known as MIMO MC-DS (multi-carrier direct sequence) CDMA.



Daniel Basilio
MEng

Channel Estimation & Performance Analysis of MIMO-OFDM Schemes

Next-generation communication systems promise to offer multimedia services requiring reliable transmission at high data rates over wireless links. High-speed physical layer techniques invented to meet these challenges are, for example Ultra Wideband (UWB); Software-defined radios (SDR), Orthogonal Frequency Division Multiplex (OFDM), and multiple-input-multiple-output (MIMO) radios.

MIMO and OFDM systems are promising technologies, achieving spectral efficiency and increase throughput of wireless networks. MIMO-OFDM systems transmit independent OFDM modulated data from multiple antennas simultaneously. Dare's project researches specific challenges encountered when designing MIMO-OFDM systems, namely:

- Low complexity channel estimation algorithm for MIMO-OFDM systems and
- Performance analysis of MIMO-OFDM systems in slow and fast time varying channels.



Dare Sokoya
PhD

Methods of producing a compact antenna array, for deployment in MIMO systems.

Traditionally MIMO channel measurements and simulations have been done using dipoles and circular patch arrays. These antenna arrays are perfect for experimental validation, however, impractical for commercial utilisation. This research investigates methods of producing a compact antenna array, for deployment in MIMO systems. This research will also focus on adaptive beamforming so to increase the coverage area of this compact array. Kahesh started his PhD in 2008.



Kahesh Dhuness
PhD



**Public Transport
Monitoring System**

Simon Barnes
BEng 4



**Cognitive Radio: Design and
Modelling of a Spectrum
Measurement System**

Glen Stein
BEng 4



**Digital Radio
Mondiale System**

Hanneljie Nell
BEng 4



**A 2.4 GHz Agile WiMAX
Cognitive Radio
Implementation**

Willie van der Merwe
BEng 4



**Design and Performance
Analysis of a WiMAX Physical
Layer Implementation**

Thinus Prinsloo
BEng 4



**Remote Forest-Temperature
Monitoring System**

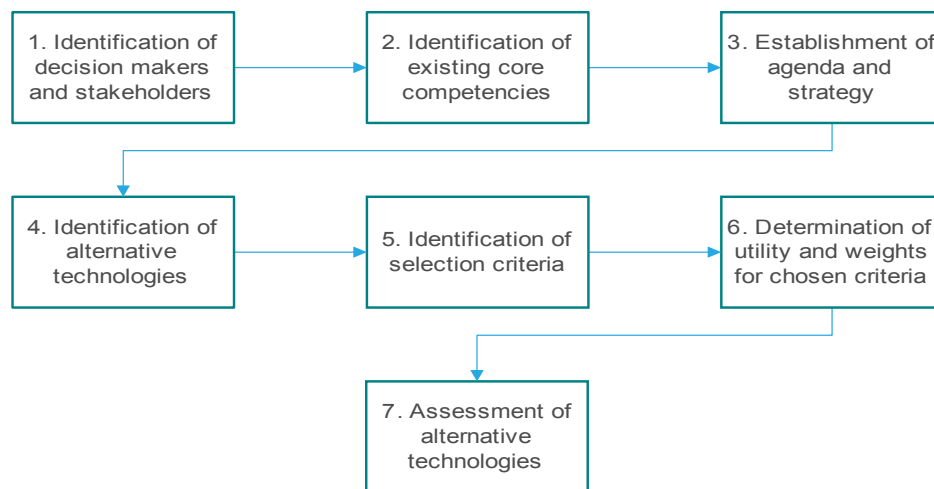
Johan van Rooyen
BEng 4

Research Summary: K A Ruder

A TECHNOLOGY SELECTION FRAMEWORK FOR THE TELECOMMUNICATIONS INDUSTRY

Technology selection is a core technology management process. It describes the process of making a choice between a number of distinct alternatives. The selection of technologies is one of the most challenging decision-making areas that the management of a company encounters. Technology selection is a process that is closely linked to other business processes, and is associated with the broader technological, organizational, and business environment.

There is no formal technology-selection framework which considers the criteria that are relevant to telecommunication service providers in a developing country. The objective of this study was to develop and test a new technology-selection model illustrated below. To test the model, two case studies were conducted at companies in the telecommunication industry.



Key findings of the study were as follows: Technology selection frameworks exist in the organizations. They are used when the decision is important enough to warrant documentation of how the decision was arrived at. These frameworks are not mathematically intense as they are used by people of varying levels of skills. Also, they are simple in nature so as to be transparent and easy to understand by everyone. The selection frameworks do specify some documentation to be used when making the decision and produces documentation; however this is only known by the team leader. Organization protocols do require documentation for the decision process which is not specified by the technology-selection framework.

Research Summary: D Sokoya



CHANNEL ESTIMATION AND PERFORMANCE ANALYSIS OF MIMO-OFDM SCHEMES

Multiple-input-multiple-output and Orthogonal Frequency Division Multiplexing systems are promising technologies in achieving spectral efficiency and increase throughput of wireless networks. A MIMO-OFDM system transmits independent OFDM modulated data from multiple antennas simultaneously.

This project proposes to research into some of the challenges encountered when designing MIMO-OFDM systems. These specific challenges include, but are not limited to:

- Low-complexity channel estimation algorithm for MIMO-OFDM systems
- Performance analysis of MIMO-OFDM systems in both slow time-varying and fast time-varying channels.

In achieving the proposed objective of the research, it is important to look into the performance of various MIMO-OFDM schemes in a frequency-selective channel. The first output of the research was a paper submitted to IEEE AFRICON 2007 held in Namibia. This paper investigated the performance of a Super Orthogonal Space-Time Trellis Code (SOSTTC) scheme in a frequency-selective channel (shown in Figure 1). A new decoding trellis for SOSTTC in such environment was proposed as well.

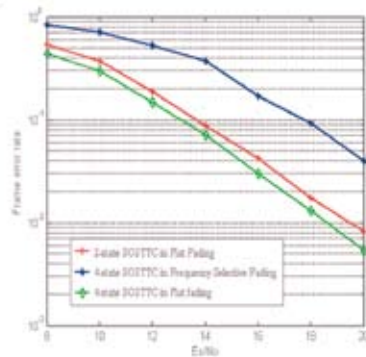


Figure 1. FER of SOSTTC schemes with STTC-OFDM and STBC with $5\mu s$ delay spread

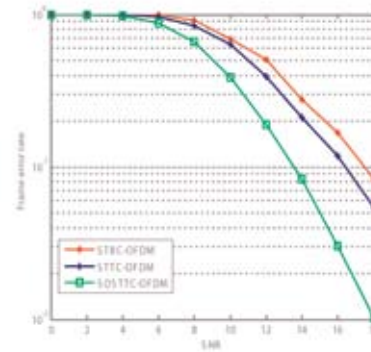


Figure 2: FER Performance of 16-state SOSTTC-OFDM 16-state $N_t=2, N_r=1$ in fading channel

The research went further to look at the performance of a MIMO-OFDM scheme (i.e. STBC - FDM, STTC-OFDM and SOSTTC-OFDM) in a frequency-selective channel with delay spreads. A paper output of this was accepted for presentation at MELECON 2008 to be held in France in May. Part of the result presented in the paper is shown in Figure 2 above.

Research Summary: K P Maré

IMPLEMENTATION OF A REALISTIC MIMO PLATFORM FOR EVALUATING CODING TECHNIQUES

The goal of the research was to implement a realistic MIMO platform according to the IEEE 802.16e-2005 standard (WiMAX) to research and study the effects of modern coding techniques in a mobile wireless channel. The simulator was developed in C++ where each building block of the platform can be illustrated by Figure 1

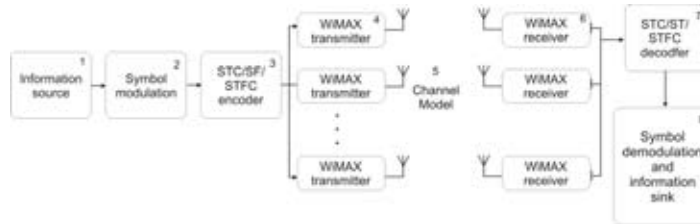
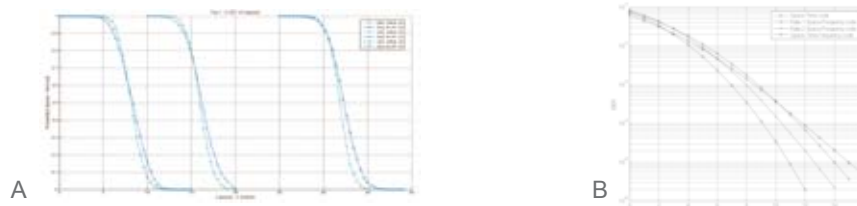


Fig. 1. Simulator platform for the MIMO-WiMAX interface

The MIMO-WiMAX platform was created according to the WirelessMAN-OFDMA air specification and is capable of simulating space-selective, time-selective and frequency-selective fading conditions. The simulator can simulate any arbitrary power-delay profile without increasing the receivers sampling frequency. The simulator has the capability of simulating quasi-static fading conditions as well as blockfading conditions. The effects of using MIMO can be illustrated by the following capacity graphs :



From Figure 2 (A), one can clearly see the effects on capacity when one increases the number of antennas used. One can see that an 8x8-antenna setup has much higher capacity compared to the 2x2-antenna setup. If we look at an outage capacity of 10%, one actually gains in capacity in frequency-selective conditions.

The platform was also used to simulate recent coding technologies which consist of space-time codes (STC), space-frequency codes (SFC) and space-time-frequency (STFC) codes. One can clearly see the gain from the STFC codes compared to the STC/SFC. The STFC simulations on the MIMO-WiMAX platform formed a set of newly defined codes which can be incorporated into the standard in addition to the current single-symbol maximum-likelihood codes.

Further research will include a study of a combination of LDPC with these STFC in block-fading conditions. The amount of diversity gain obtained by the STFC results in an almost Gaussian distribution of the log-likelihood ratio outputs, which will provide a significant performance gain compared to current LDPC-MIMO systems.

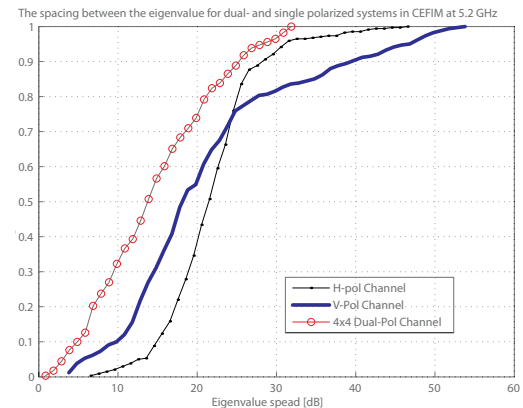
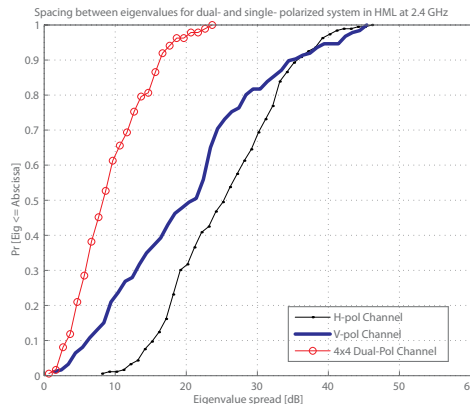


Research Summary: L Nair



INDUSTRIAL WIDEBAND MIMO CHANNEL CHARACTERIZATION

The suitability of MIMO architectures employing either single- or dual-polarization antennas is presented, with the purpose of identifying not only which architecture provides better average-capacity performance, but also which is more robust for avoiding low-channel rank. This robustness is assessed by studying the empirical eigenvalue distributions obtained from indoor measurements at both 2.4 GHz and 5.2 GHz in a typical office environment, as well as an industrial environment, where it is expected that systems with high robustness will be required for reliable and demanding applications. The measurement system employs 8-element arrays of dual-polarized patch antennas, and for both environments the performance of three 4x4 subsystems (dual-polarized, vertical-polarized and horizontal-polarized) are compared in terms of the average capacity attained by these systems and their eigenvalue distributions. Average capacities are found to be only marginally different, indicating little advantage of dual-polarized elements for average performance. However, the eigenvalue analysis indicates that the dual-polarized system is more robust for multiplexed MIMO communications, by providing two orthogonal channels with more similar gain.





A. JOURNAL ARTICLES PUBLISHED

2005

- BTJ Maharaj, JW Wallace, LP Linde and MA Jensen, *Frequency scaling of spatial correlation from co-located 2.4 GHz and 5.2 GHz wideband indoor MIMO channel measurements*, IEE Electronics Letters, Vol. 41, no. 6, March 2005, pp 336-337.
- BT Maharaj, JW Wallace, LP Linde and MA Jensen, *Linear dependence of double-directional spatial power spectra at 2.4 and 5.2 GHz from indoor MIMO channel measurements*, IEE Electronics Letters, vol. 41, no. 24, pp 1338-1340, November 2005.

2006

- BT Maharaj and LP Linde, *Geometric Modelling of a spatially correlated MIMO fading channel*, SAIEE Africa Research Journal, Vol.97, no.2 June 2006.

2008

- BT Maharaj, JW Wallace, LP Linde and MA Jensen, *A low cost open-hardware wideband MIMO wireless channel sounder*, IEEE Transactions on Instrumentation and Measurement, accepted for publication, February 2008.

B. JOURNAL ARTICLE SUBMISSIONS

- LR Nair, BT Maharaj and JW Wallace, *Performance and robustness of dual-polarized MIMO systems in industrial and office environments*, IEEE Transactions in Vehicular Technology, March 2008
- BB Varghese and BT Maharaj, *Modelling of a Spatially Correlated MIMO Wireless Channel*, SAIEE Africa Research Journal, November 2007.
- BP Salmon, W Kleynhans, JC Olivier and BT Maharaj, *Teaching the Theory of Channel Estimation and Coding via a Mobile WiMAX Simulation Platform*, IEEE Transactions in Education, November 2007.
- LR Nair and BT Maharaj, *Capacity Analysis of an Indoor Industrial Environment using a Dual-Polarized MIMO System*, SAIEE Africa Research Journal, October 2007.

C. PEER-REVIEWED CONFERENCE PAPERS PUBLISHED

2005

- BT Maharaj, LP Linde, JW Wallace and MA Jensen, *A cost-effective wideband MIMO channel sounder and initial co-located 2.4 GHz and 5.2 GHz measurements*, Proceedings of IEEE International Conference on Acoustics Speech and Signal Processing (ICASSP'05), Philadelphia, USA, March 2005.
- BT Maharaj, JW Wallace, MA Jensen and LP Linde, *Co-located indoor 2.4- and 5.2-GHz MIMO channel measurements: Frequency scaling of capacity and correlation*, Proceedings of IEEE ICT'05, Cape Town, South Africa, May 2005.
- BB Varghese and BT Maharaj, *A Space-Time Model for Correlated MIMO Fading Channels*, Proceedings of IEEE ICT'05, Cape Town, South Africa, May 2005.
- DJ Summers, BT Maharaj and JW Wallace, *A 2.4 GHz wideband PC-based SDR receiver platform*, Proceedings of IEEE ICT'05, Cape Town, South Africa, May 2005.
- LR Nair and BT Maharaj, *Efficient Digital GSM/GPRS Metering for Rural Electrification*, Proc. of International Union of Radio Science General Assembly (URSI GA'05), Delhi, India, 24-29 October 2005.

2006

- BT Maharaj and LP Linde, *Frequency scaling of capacity for a co-located 2.4 and 5.2 GHz wideband indoor MIMO circular array system*, IEEE ICTe Africa Conference, Nairobi, Kenya, 17-21 May 2006.
- BT Maharaj, JW Wallace and LP Linde, *Wideband MIMO Channel sounder: capacity and spatial correlation under 2.4 and 5.2 GHz co-located conditions*, SATNAC 2006, Western Cape, 3-6 September 2006.
- EJ Meyer and BT Maharaj, *Implementation and Analysis of a facial recognition system combining a neural network and linear subspace model*, SATNAC 2006, Western Cape, 3-9 September 2006.
- L van Dyk, E Horak, BT Maharaj, L Liebenberg and L Barlow, *Project based learning: Lessons learned from Innovation 110*, 3rd African Regional Conference on Engineering Education, Pretoria, South Africa, September 2006.

2007

- BT Maharaj, LP Linde and JW Wallace, *MIMO Channel Modelling: the Kronecker model and maximum entropy*, Proc. IEEE Wireless Communications and Networking Conference (WCNC), Hong Kong, 11-15 March 2007, CDROM.
- JM Groenewald and BT Maharaj, *MIMO channel synchronization using Golay Complementary Pairs*, Proc. IEEE Africon Conference (Africon'07), Windhoek, Namibia, 26 – 28 September 2007, CDROM.
- LR Nair and BT Maharaj, *Capacity Analysis of an Indoor Industrial Environment Using a Dual-Polarized MIMO System at 2.4 GHz and 5.2 GHz*, Proc. IEEE Africon Conference, (Africon'07), Windhoek, Namibia, 26 – 28 September 2007, CDROM.
- O Sokoya and BT Maharaj, *Performance of Super-Orthogonal Space-time Trellis Code in a Multipath Environment*, Proc. IEEE Africon Conference (Africon'07), Windhoek, Namibia, 26 – 28 September 2007, CDROM.
- DJ Basilio, LP Linde and BT Maharaj, *Power and spectrally efficient multi-dimensional WCDMA modem employing CPM*, Proc. IEEE Africon Conference (Africon'07), Windhoek, Namibia, 26 – 28 September 2007, CDROM.
- JW Wallace and BT Maharaj, *Accurate MIMO Channel Modeling: Correlation Tensor vs. Directional Approaches*, Proc. IEEE Global Communications (Globecom'07), Washington DC, USA, 26 – 30 November 2007, CDROM.
- LR Nair, BT Maharaj and JW Wallace, *Capacity and Robustness of Single- and Dual-Polarized MIMO Systems in Office and Industrial Indoor Environments*, Proc. IEEE Globecom'07, Washington DC, USA, 26 – 30 November 2007, CDROM.

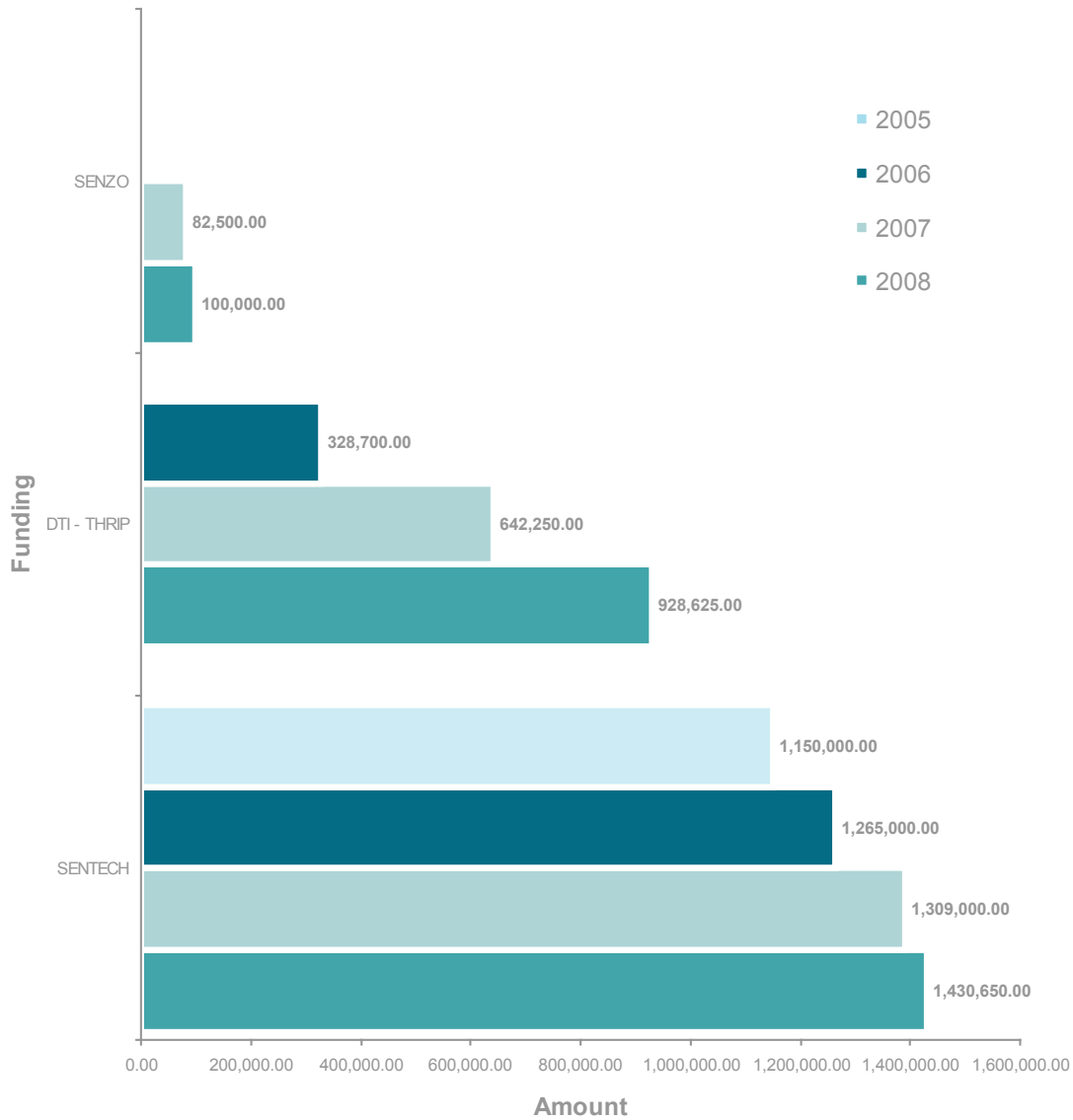
D. INVITED INTERNATIONAL PEER REVIEWED CONFERENCE PAPERS PUBLISHED

- BT Maharaj, JW Wallace and MA Jensen, *Comparison of double directional channel response at 2.4GHz and 5.2GHz from indoor co-located wideband MIMO channel measurements*, Proc. International Union of Radio Science General Assembly (URSI-GA), Delhi, India, October 2005.
- JW Wallace, BT Maharaj and MA Jensen, *Experimental evaluation of the MIMO wideband channel temporal variation*, Proc. International Union of Radio Science General Assembly (URSI-GA), Delhi, India, October 2005.

E. 2008 PEER-REVIEWED CONFERENCE PAPERS SUBMITTED

- O Sokoya and BT Maharaj, *Performance of Space Time Coded Orthogonal Frequency Division Multiplexing Schemes with Delay Spreads*, 14th IEEE Mediterranean Electrotechnical Conference (MELECON 2008), Ajaccio, France, May 5-7, 2008, accepted for publication.
- K Ruder, M Pretorius and BT Maharaj, *A Technology Selection Framework for the Telecommunications Industry in Developing Countries*, IEEE International Communications Conference (ICC'08), Beijing, China, May 2008, accepted for publication.
- KP Maré and BT Maharaj, *Performance Analysis of modern Space-Time codes on a MIMO-WiMAX Platform*, IEEE Personal Indoor and Mobile Communications (PIMRC'08), Cannes, France, September 2008.

Financial



Financial Reports 2007

Sentech Chair

Income and expenditure report for the period 1 January 2007 to 31 December 2007

Income	1,590,739.46
Sentech	1,309,000.00
Senzo IT	82,500.00
IEEE Africon	6,578.95
Interest	192,660.51
Expenditure	695,425.60
Advertisements	42,779.55
Salaries	272,410.28
Refreshments	15,011.74
Conference	9,919.36
Travelling	61,758.98
Internet	2,127.83
Bursaries	232,500.00
Postage	286.94
Computer equipment	17,270.00
Office equipment	2,726.79
Audiovisual equipment	5,002.32
Computer training	150.00
Small equipment	3,915.80
Lab equipment	
Stationery	15,278.50
Building alterations	7,166.47
Sundry expenses	7,121.04
Surplus / (deficit) for the period	895,313.86
Surplus / (deficit) at the beginning of the period	1,354,983.85
Surplus / (deficit) at the end of the period	2,250,297.71

The report is compiled in accordance with the books of the University of Pretoria


Director of Finance

Date 2008-03-17

Direkteur van Finansies
Director of Finance
Molaoedi wa Ditshislete
UNIVERSITEIT VAN
UNIVERSITY OF
YUNIBESITHI YA
PRETORIA