POSITIONING AND WIRELESS TECHNOLOGY CENTRE
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Introduction

Positioning and Wireless Technology Centre (PWTC) is an inter-school research centre hosted by the School of Electrical and Electronic Engineering (EEE) with participation from the School of Civil and Environmental Engineering (CEE), School of Mechanical and Production Engineering (MPE), and School of Computer Engineering (SCE). PWTC was established in March 1999 and was formerly known as Global and Positioning Centre (GPSC). Our vision is to be a Centre of Excellence in Who, Where and When (WWW) technologies and our mission is to lead and promote Research, Product Innovation and Training in Identification, Positioning and Tracking technologies.

The Centre has formalised three research groups undertaking R&D activities in the relevant focus areas: Wireless Network, RF Identification and Tagging (RFID) and Global Navigation Satellite System & Applications.

PWTC has grown from strength to strength in terms of human resources development and R&D achievement. Major achievements in 2004 include the following:

• 7 ongoing projects with total research funding of S$3.008 million, of which around 82% is from external sources.
• Participation in 2 major exhibitions.
• Publication of more than 50 papers in renowned international journals and international conferences.

Although PWTC research activities involve staff and students of EEE, CEE, SCE and MPE, this section only reports those that involve EEE staff and students.

WIRELESS NETWORK RESEARCH PROGRAM

Objectives

The Wireless Network Research Programme aims to excel in the research and development of advanced wireless networking technology and solutions. Currently, our R&D activities are mainly focused on the PHY (physical), MAC (medium access control) and networking layers of broadband wireless systems. Specific areas of interest include:

1. Broadband wireless local/personal area network (WLAN/ WPAN)
   • Advanced modulation and coding techniques: MIMO (multiple-input multiple-output) coding, OFDM (orthogonal frequency division multiplexing), Turbo/low-density-parity-check codes, multi-user detection etc.
   • Interference management, security etc.
   • Development of software radio test-bed.

2. Mobile ad hoc network (MANET)
   • MAC and routing protocols enhancements: QoS (quality of service) routing, multicast routing, multi-channel MAC etc.
   • Development of test-bed on PDAs/laptops.
   • Sensor network.
3. Ultra-wideband (UWB)
   - PHY, MAC and MANET issues in UWB.
   - Standards and applications: IEEE 802.15. 3a/4a, precision positioning etc.
   - Coexistence with WLAN, GPS systems.
4. Wireless Propagation Study
   - Propagation prediction and development of clutter database for digital TV (DTV).
   - Spatial diversity for urban DTV
5. Non-GPS positioning technologies
   - Indoor positioning based on WLAN/UWB

Highlights of Research Activities

Good achievements have been made in the unification and design of full-rate full-diversity quasi-orthogonal space-time block codes (QO-STBC) with minimum decoding complexity, and in the detailed modelling of coding loss due to spatial or path correlation in frequency-selective MIMO channels. Novel low-complexity adaptive OFDM and multi-carrier CDMA (code division multiple access) schemes have been proposed and shown to give impressive performance gains. Pre-coding schemes of OFDM signal for mitigating distortion induced by fast fading or for enabling better channel estimation, better code shortening and efficient decoding schemes for Turbo product codes and LDPC (low-density parity check) codes, new geometric models for UWB channels, low-complexity and blind multi-user detectors for coded CDMA systems, have been developed. A new MAC protocol for MANET based on two-phase CDMA coding also has been developed and shown to outperform conventional protocols.

A software radio test-bed for the IEEE 802.11a/g WLAN modem has been developed. The PHY layer is developed on FPGA, while the MAC services are executed by an ARM940T processor with some time-critical MAC functions implemented in FPGA. Development of a new test-bed for the next-generation 802.11n MIMO WLAN is currently in progress. An externally-funded project to develop an enhanced MAC protocol for time-bounded applications is also ongoing.

A MANET test-bed based on the AODV, DSR and OLSR routing algorithms has also been developed. It consists of notebook computers and PDAs equipped with IEEE 802.11a/b/g wireless LAN cards and running on Windows/Linux operation systems. It is capable of multihop communication, automatic configuration and link repair, multimedia streaming, and seamless connection to the Intranet, Internet as well as the cellular network. Externally-funded and internal projects have been undertaken to extend this technology to QoS-constrained applications and large/scalable networks.

Extensive measurements have been carried out to study the coverage probability for the fixed and portable DTV reception. Measurement and post-processing techniques have been developed. A clutter model has been developed for a proprietary coverage prediction software. Comparisons between measured and predicted field strengths are within 2 to 5 dB.

A MANET test-bed based on WLAN interface at the IDA UWB Exhibition 2004

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Assoc Prof Soong Boon Hee

Assoc Prof Erry Gunawan
## Ongoing Research Projects

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<th>Principal Investigator</th>
<th>Funding</th>
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<tr>
<td>Development of Point Coordinator Function (PCF) Capability of the IEEE 802.11 Standard</td>
<td>Law Choi Look</td>
<td>Thales ($70k)</td>
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<tr>
<td></td>
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<td>NTU ($70k)</td>
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<tr>
<td>Adaptive and Spread Spectrum Space-Time Coding Systems</td>
<td>Guan Yong Liang</td>
<td>DSO ($80k)</td>
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<tr>
<td>Design and Optimization of a Turbo Product Code System</td>
<td>Guan Yong Liang</td>
<td>DSO ($50k)</td>
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<tr>
<td>Quality of Service Multicast Routing in Mobile Ad Hoc Network</td>
<td>Soong Boon Hee</td>
<td>DSO ($71k)</td>
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<td>NTU ($60k)</td>
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<tr>
<td>Real-Time Network Planning and Management Tools (Phase II)</td>
<td>Zhang Liren, Bi Guoan</td>
<td>DSTA ($450k)</td>
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<td>Universal Multimedia Access Over 4G Wireless Networks</td>
<td>Cai Jianfei, Zhang Liren</td>
<td>A*STAR ($600k)</td>
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Research Projects Completed in 2004

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<tr>
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<tr>
<td>Mobile Wireless Communication Capability and DGPS for UAV</td>
<td>Soong Boon Hee</td>
<td>ST Aero ($130k)</td>
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<td>NTU ($130k)</td>
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<tr>
<td>Quality of Service Predictions for DTV Reception</td>
<td>Ong Jin Teong</td>
<td>MDA ($336k)</td>
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<td>NTU ($144k)</td>
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<td>Simulation and Modeling Direct Sequence Spread Spectrum Satellite Modem</td>
<td>Law Choi Look</td>
<td>Agilis ($25k)</td>
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MEng and PhD Theses Completed in 2004

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<tr>
<td>Performance Analysis and Enhancements of Multi-carrier Wireless Transmission Systems</td>
<td>PhD</td>
<td>Zhang Keli</td>
<td>Guan Yong Liang</td>
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<tr>
<td>MC-CDMA (Multi-Carrier CDMA) for 3G Wireless Communication System</td>
<td>PhD</td>
<td>Hou Zhihua</td>
<td>Vimal Kishore Dubey</td>
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<tr>
<td>Scalable Quality of Service (QoS) over Broadband Internet and Next Generation Mobile Networks</td>
<td>PhD</td>
<td>Zaw Min Naing</td>
<td>Zhang Liren</td>
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<tr>
<td>Protocol Design, Modeling and Performance Analysis for Mobile Ad Hoc Networks</td>
<td>PhD</td>
<td>Leng Supeng</td>
<td>Zhang Liren</td>
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<tr>
<td>Modeling and Performance Analysis of IP Traffic with Multi-Class QoS in Mobile Ad Hoc Network</td>
<td>MEng</td>
<td>Zhong Xuxia</td>
<td>Zhang Liren</td>
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<tr>
<td>Reduced Complexity Multiuser Detection for Coded CDMA</td>
<td>MEng</td>
<td>Hu Chuanzen</td>
<td>Teh Kah Chan</td>
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<tr>
<td>Performance Analyses of Coherent Fast FHSS/MPSK Systems over Non-fading and Fading Channels with Partial Band Noise Jamming and AWGN</td>
<td>MEng</td>
<td>Kang Junjin</td>
<td>Teh Kah Chan</td>
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Seminars

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<th>Affiliation</th>
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<tr>
<td>Guan Yong Liang</td>
<td>Turbo Coding and Decoding: Principles and Practices</td>
<td>EEE, NTU</td>
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Selected Publications in 2004

RF IDENTIFICATION AND TAGGING PROGRAM

Objective

The objective is to develop state-of-the-art technology for UWB system that can be integrated into wireless-LAN networks to provide identification as well as positioning. Emphasis is placed on developing various components for the UWB system. A comprehensive set of CPW passive components, in joint effect with the Microelectronics School of EEE, has also been developed which is suitable for vehicle collision avoidance radar operating at 77 GHz. In addition, test of passive RFID tags for the compatibility of 900 MHz RFID products in Singapore market with different regulations will also be undertaken.

Highlights of Research Activities

PWTC has been actively involved in the design and implementation of the UWB transceiver. Recently, we have successfully built our own low-cost FCC-compliant UWB transmitter. The transmitter consists of a gaussian pulse generator capable of generating pulses of 1.4V at a pulse width of 160ps. The gaussian pulse is further shaped by a fifth order quarter-wavelength-coupled shorted-stub bandpass filter in order to obtain a FCC-compliant UWB signal. The signal is then fed into a miniature broadband planar antenna of size 3cm by 3cm operating from 3.55GHz to 11.2GHz fabricated in-house on a FR4 substrate. Due to the planar design of all the transmitter components, such a set-up is used to emulate a RFID beacon card. UWB ranging studies have been carried at various locations in Singapore researching the performance of UWB antennas will be used in studying

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the transfer function of the antennas in the near future. Once the antennas are fully characterized, the overall UWB system (transceiver together with antennas) can be analyzed.

Ultra-wideband receiver circuits are also under investigation. Various circuit topologies for UWB matched filter and correlation receiver have been proposed and studied.

Various MMIC circuits using in-house fabrication capability in Microelectronic Centre of the School of EEE have also been designed and developed. Examples of such MMIC circuits are filter, oscillator and amplifier circuits based on GaAs technology. In addition, an extensive set of CPW passive component library was also developed and modeled up to 100 GHz using the in-house 110 GHz HP8510XF vector network analyzer from Agilent together with the probe station from Cascade Microtech. These MMIC components are suitable for 77 GHz vehicle collision avoidance radar applications.

To test the compatibility of 900 MHz RFID products in the Singapore market with different regulations, testing of passive RFID tags will be undertaken. The tests will focus on the read/write range and read/write rate of the RFID systems.

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Asst Director

Mr Wang Quanxin
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Ms Shi Yiqiong
Project Officer
Ongoing Research Projects

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<tr>
<td>Development of Millimeter-Wave Antennas (60GHz)</td>
<td>Shen Zhongxiang</td>
<td>NicT ($72k)</td>
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Research Projects Completed in 2004

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<tr>
<td>Development of Optical Packages</td>
<td>Shen Zhongxiang</td>
<td>SEI-NTU ($550k)</td>
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MEng and PhD Theses Completed in 2004

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<tr>
<td>A Hybrid FD-MM Technique for predicting shielding effectiveness of metallic enclosures with apertures</td>
<td>MEng</td>
<td>Feng Chao</td>
<td>Shen Zhongxiang</td>
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Selected Publications in 2004

GLOBAL NAVIGATION SATELLITE SYSTEM & APPLICATIONS PROGRAM

Objective

The research areas and topics of interest in the Global Navigation Satellite System & Applications Programme include:

1. High accuracy positioning systems and applications such as DGPS reference network and centimetre level positioning systems and algorithms
2. Intelligent in-vehicle navigation system
3. Multi-objective routing and map matching algorithm
4. GPS-based Attitude determination of LEO micro-satellite using the LAMBDA method

Highlights of Research Activities

Assisted-GPS improves the performance of GPS receivers by providing them with data that they would ordinarily have to download from the GPS satellites. With A-GPS, GPS receivers can operate faster with information, such as the satellite ephemeris, from which the receiver can estimate the satellite Doppler ahead of time, thereby dramatically reducing the required freq/delay space that must be searched. A combination of synchronized signals from wireless network and available GPS and satellite signals improves sensitivity and availability.

With massive parallel correlation, a GPS receiver can accumulate many copies of the encoded GPS signal, even when indoors where the signal is weaker than outdoors and operate in environments where GPS signals are over 30dB lower than outdoors. In outdoor situations, this means that signal acquisition occurs almost instantaneously with aiding.

PWTC is investigating the potential applications of A-GPS to compliment its Location-Based Service (LBS) projects. Currently, we are evaluating several technologies and testing their operational accuracies within the laboratories and buildings.

A technical study for the feasibility of developing an active antenna array for GPS receivers was conducted. The antenna array was designed to reject jamming signal from some known direction and steer its radiation pattern to the desired satellites’ direction.

The objective of this feasibility study is to formulate a realistic system requirement and to propose hardware and software implementations for our client. A 4-element superstrate antenna array was designed, built and tested using the in-house anechoic chamber. The measured radiation pattern of the antenna array was captured and fed to the ADS simulation software for simulating the nulling of the interference from three fixed directions.

The software is used to characterize the anti-jamming margin of the antenna array with the implementation of the phase shifters and attenuators in the phase array system by steering the beam in the direction of the desired signal, and at the same time, placing nulls in the direction of the jammers. A feasibility report was generated for this project.

Locating objects and people outdoors is becoming common using technologies such as Global Positioning System (GPS). However, accurately estimating location in indoor environment remains a complex problem due to indoor channel characteristics. The use of existing wireless LAN (WLAN) infrastructure would enable a low-cost implementation of indoor positioning.

- Guided tours with wireless PDAs in museums and exhibitions.
- Location-specific advertisements by sending location-based information to users.
- Locating the nearest restaurant/bookstore or a friend on campus.
- Finding personnel or equipment on demand.
- Locating and guiding wireless LAN users out of buildings under fire incidents.
- Billing based on location.

PWTC has evaluated a WLAN-based positioning software. The fundamental challenge of Wi-Fi positioning is implementing the right inferring location algorithm to accurately position a user in a dynamic wireless environment, which changes due to movement of people in the background.
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Research Projects Completed in 2004

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<tr>
<th>Project Title</th>
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<tr>
<td>Development of An Active Array for GPS Receiver (I)</td>
<td>Law Choi Look</td>
<td>DSO ($50k)</td>
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<tr>
<td>Evaluation of WLAN indoor positioning software</td>
<td>Lee Yee Jin Andrew</td>
<td>IDA (in kind)</td>
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<tr>
<td>GPS-based Attitude Determination for a Microsatellite</td>
<td>MEng</td>
<td>Dai Lin</td>
<td>Ling Keck Voon</td>
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