National Taiwan University

Graduate Institute of Communication Engineering Newsletter

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In this issue

Technology Developed in GICE

Remote Vital-Sign Detector Using a Phase- and Self-Injection-Locked Oscillator

from Electromagnetics Group

New microwave applications in the remote sensing of the vital signs from the cardiopulmonary activities have been conceived recently. Various techniques have been reported for health-assistance devices to monitor infants at risk of sudden infant death syndrome or adults with sleep disorders, and life detectors for earthquake rescue of burned victims in past decades [1]. They enable the physicians to keep patients suffering from chronic illness or the elders under surveillance in preferred environment outside the hospital for better living quality. Without uncomfortable on-body electrodes, problems such as skin irritation and electrical wire connections are easily eliminated. These applications have increased the interests in the potential market of the microwave vital-sign detectors.

The vibration of the chest wall due to cardiopulmonary activities modulates the phase of the radar signal reflected off the subject since it has a time-varying position while a net zero velocity. The receiver extracts the information of the respiration and heartbeat rates from the phase variation of the reflected signal. The periodic physiological motions of the human body associated with the cardiopulmonary system has typical chest wall displacements of 0.01~0.1 mm for heartbeat and several millimeters for breathing, thus necessitates high sensitivity radar for accurate detection.

Continuous-wave (CW) radars have been reported a simpler topology than pulse radars as the preferred choices for low-cost vital-sign sensing applications. Most reported CW radars for vital-sign detection are basically simple direct-conversion RF transceivers, which has a system block diagram illustrated in Fig. 1. The local oscillator (LO) generates a microwave signal which is amplified by a power amplifier and illuminates the area covered by the directional transmitting antenna. The receiver consists of a low noise amplifier (LNA) and a

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GICE Honors

Prof. Ming-Syan Chen

Outstanding Research Award of National Science Council

Prof. Wanjiun Liao

Outstanding Research Award of National Science Council

Prof. Hung-Yu Wei

K. T. Li Young Researcher Award from The Institute of Information and Computing Machinery

Message from the Director

Tzong-Lin Wu

Professor & GICE Director

With beautiful azaleas bloom in the NTU campus, professors and students in GICE have a good start in 2013. Prof. Ming-Syan Chen and Prof. Wanjing Liao received the Outstanding Research Award of NSC, which is a great honor in Taiwan for the academic achievement. In addition, this issue highlights an interesting technology about the remote vital signal detection, which has attracted well attention in health care society recently. Many seminars/workshops and invited talks from worldwide experts are held in GICE with good interaction between students and speakers in several cutting edge research area.

Please have a cup of coffee, and enjoy the reading of this latest GICE Newsletter!

Technology *(continued from page 1)*

mixer, which is the Doppler phase detector and down-converts the carrier signal to baseband. After low pass filtering, the baseband signal can be sampled and analyzed to acquire the vital-sign information.

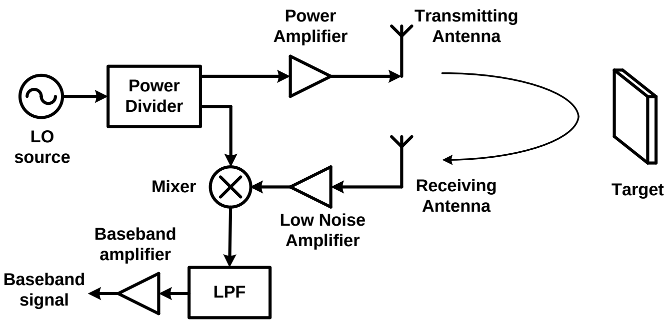

Fig. 1. System block diagram of the conventional CW Doppler radar for physiological motion detection with direct-conversion receiver.

Although many works have been reported, there are still some stringent issues in regard to reliable vital-sign detection and radiated power reduction. This article introduces a Doppler radar based on a phase- and self-injection-locked (PSIL) oscillator to provide highly sensitive detection with low noise. The phase-locked oscillator (PLO) is widely deployed in various circuits and systems to offer a pure sinusoidal signal. However, the PLO is subject to interferences which are injected via parasitic coupling paths, often cause frequency pulling and hence degrade the spectral purity. This work alternatively exploits this usually intolerable effect and provides an approach to detect the vital signs by intentionally injecting the Doppler reflected signal into a PLO to establish a self-injection-locked (SIL) loop. The SIL technique has been prevalently used in microwave and optical circuits to reduce the frequency and phase noise, in which a certain part of the oscillator output signal is coupled and injected back to lock the oscillator itself. It has been shown that an SIL oscillator is particularly suitable for detecting the low frequency modulated signal such as the vital-sign information [2].

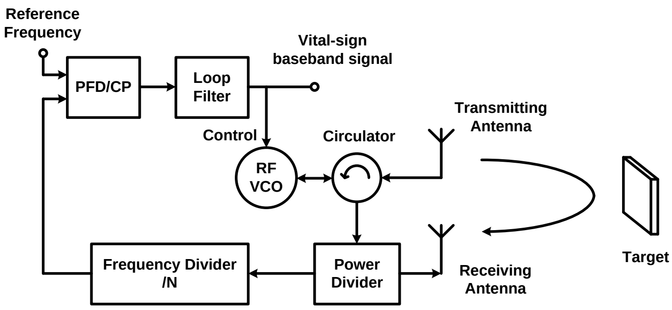

Fig. 2. System block diagram of the PSIL vital-sign detection Doppler radar.

The PSIL radar has the advantages of both the phase-locked oscillators and self-injection-locked oscillators [3] to achieve superior signal-to-noise ratio gain against the low-frequency phase noise in the bandwidth containing the vital-sign information. Consequently, it can serve for long-range detections with less transmitted power. Fig. 2 displays the system block diagram of the Doppler radar based on the PSIL oscillator. The received Doppler signal is injected into the voltage-controlled oscillator (VCO) through the circulator to form an SIL loop. Then, the SIL loop is phase locked by the PLL to stabilize the output frequency and reduce the in-band phase noise. The Doppler injection signal results in an output phase perturbation of the VCO which is detected by the phase frequency detector (PFD). The charge pump (CP) circuit and the loop filter transform the output of the PFD into a voltage for tuning the intrinsic oscillation frequency of the VCO. As a result, the VCO tuning voltage controlled by the PLL is the vital-sign output voltage that reflects the phase variation of the Doppler signal. Therefore, the baseband signal can be obtained by directly sampling the VCO tuning voltage controlled by the phase-locked loop without any demodulation circuits. Note that the demodulation mechanism of the PSIL architecture differs from that of conventional PLL FM/PM demodulators since the

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Doppler phase-modulated signal is fed through the injection locking mechanism of the oscillator in the PSIL radar, rather than through the PFD.

A prototype circuit is implemented by the hybrid dual-tuning VCO and the commercial PLL synthesizer IC to demonstrate the feasibility of the proposed technique. In the vital-sign detection experiments, the human subject sits in front of the prototype Doppler radar at the distances of 4 meters. The antenna beam points to the front side of the chest wall. Both the transmitting and receiving antennas are commercially available with 12 dBi gain.

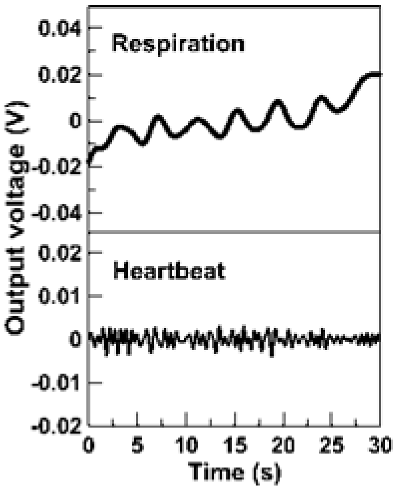

Fig. 3. Measured vital-sign voltage waveforms of the PSIL radar at the range of 4 m.

Fig. 3 shows the filtered respiration and heartbeat waveforms of the human subject at the distance of 4 m. The obvious variation in spectral peaks observed at very low frequencies is primarily due to the random body movement. The respiration and the heartbeat rates are determined by the Fourier analysis of the time domain waveforms. Fig. 4 shows the frequency spectra. The respiration and the heartbeat rates are 13 beats/min and 55 beats/min, respectively. At 2.4 GHz operating frequency with −22 dBm average transmitted power, experimental results demonstrate successful detection of breathing and heartbeat from a distance of 4 m. The proposed PSIL radar architecture can be further monolithically integrated for compact and reliable sensors in the future.

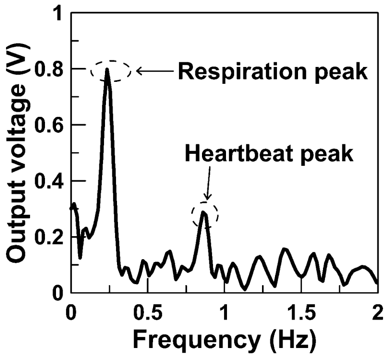

Fig. 4. Measured frequency spectra of the PSIL radar at the range of 4 m.

Reference
[1] C. Li and J. Lin, "Recent Advances in Doppler Radar Sensors for Pervasive Healthcare Monitoring," in Proc. Asia-Pacific Microw. Conf., Dec. 2010, pp. 283–290.
[2] F.-K. Wang, C.-J. Li, C.-H. Hsiao, T.-S. Horng, J. Lin, K.-C. Peng, J.-K. Jau, J.-Y. Li, and C.-C. Chen, "A Novel Vital-Sign Sensor Based on A Self-Injection-Locked Oscillator," IEEE Trans. Microw. Theory Tech., vol. 58, pp. 4112–4120, Dec. 2010.
[3] P.-H. Wu, J.-K. Jau, C.-J. Li, T.-S. Horng, and P. Hsu, "Phase- and Self-Injection-Locked Radar for Detecting Vital Signs with Efficient Elimination of DC Offsets and Null Points," IEEE Trans. Microw. Theory Tech., vol. 61, pp. 685–695, Jan. 2013.

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Spatial Correlation of Multiple Antenna Arrays in Wireless Communication Systems

from Communication and Signal Processing Group

For the next generation of wireless communication technologies, a communication system employing multiple antenna arrays (with multiple-input-multiple-output (MIMO) channels) has been recognized as an appropriate manner to enhance the system's channel capacity and combat the multipath fading. Moreover, a wireless communication system using multiple antenna arrays at both the transmitter and receiver increases data rate and signal quality without requiring additional bandwidth. This fact is characterized by the well-known MIMO ergodic channel capacity (ECC) formula:

$$C = \log_2[\det(\mathbf{I} + \rho \mathbf{H}^H \mathbf{H})], \qquad (1)$$

where $\mathbf{H}$ denotes the $N_r \times N_t$ coefficient matrix of a Rayleigh fading channel. The transmit power is divided equally among all the transmit antennas. $\rho = P/N_t\sigma_n^2$, where P denotes the total power transmitted at the transmitter and

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σ_n^2 the noise variance.

However, the diversity reception method suffers from the degradation of diversity gain due to the spatial correlation of the fading signals between the array elements with limited spacing. It has been shown that spatial correlation is a function of antenna spacing, array geometrical configuration, and the angular energy distribution and affects the performance of spatial antenna arrays. Several reports have presented the results regarding the characteristics of the spatial correlation function (SCF) of uniform linear arrays (ULAs), uniform circular arrays (UCAs) and uniform concentric ring arrays (UCRAs). The closed-form formulas expressing the spatial correlations of those specific configurations of multiple antenna arrays are important for evaluating the channel capacity of wireless communication systems. However, some of them consider only the azimuth of arrival (AOA) but ignoring the effect of elevation of arrival (EOA). However, recent research work shows that the performance of the handset antenna arrays for MIMO systems is not only azimuth dependent but also elevation dependent because the handset could be randomly oriented. Moreover, maximizing the ECC with two-dimensional (2-D) antenna arrays was recently studied. Nevertheless, there are practically no researches concerning the optimum 3-D geometry of a multiple antenna array for maximizing the ECC of a spatially correlated wireless communication system.

As a result, the study of a ***closed-form*** expression of ***SCF*** for multiple antenna arrays with ***arbitrary three-dimensional*** (3-D) geometry is not available in the literature, which becomes our first achievement (Fig.1, Step1). Secondly, we pay attention to finding the ***optimum antenna array geometry*** to reduce the spatial correlation (Fig.1, Step 2, 3) and hence, ***maximize*** the ECC of wireless communication systems (Fig.1, Step 4~6).

The closed-form expression for the SCF of an arbitrary 3-D geometry of antenna arrays under a uniform angular distribution for both AOA and EOA is obtained:

$$R_s(m,n) \approx \frac{[0.5f(x_0)+f(x_1)+\cdots+f(x_{N-1})+0.5f(x_N)]}{N\sin(\varphi_0)\mathrm{sinc}(\Delta\varphi)} + \frac{\sum_{k=1}^{\infty}\left\{j^k\cos(k(\xi_0-\alpha_{m,n}))\mathrm{sinc}(k\Delta\xi)\begin{bmatrix}0.5g_k(x_0)+g_k(x_1)+\cdots+\\ g_k(x_{N-1})+0.5g_k(x_N)\end{bmatrix}\right\}}{N\sin(\varphi_0)\mathrm{sinc}(\Delta\varphi)}, \quad (2)$$

And

$$\begin{cases} f(x) = e^{j\frac{2\pi}{\lambda}r_{m,n}\cos(\beta_{m,n})\cos(x)}\sin(x)\,J_0\left(\frac{2\pi}{\lambda}r_{m,n}\sin(\beta_{m,n})\sin(x)\right), \\ g(x) = e^{j\frac{2\pi}{\lambda}r_{m,n}\cos(\beta_{m,n})\cos(x)}\sin(x)\,J_k\left(\frac{2\pi}{\lambda}r_{m,n}\sin(\beta_{m,n})\sin(x)\right), \end{cases}$$

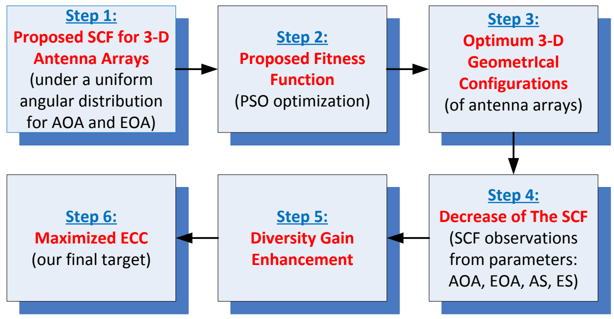

Fig. 1 The block diagram of the proposed method.

where φ_0 and $\Delta\varphi$ are the mean of the elevation angular distribution (MEOA) and the elevation spread (ES); ξ_0 and $\Delta\xi$ the mean of the azimuth angular distribution (MAOA) and the azimuth spread (AS). $\alpha_{m,n}$ represents the angle between $d_{m,n}$ and the X axis of the array coordinate, and $\beta_{m,n}$ represents the angle between $d_{m,n}$ and the Y axis of the array coordinate. The difference vector between the position vectors of the nth and the mth array elements is $d_{m,n}$. The 2-norm of $d_{m,n}$ is $r_{m,n}$, and λ denotes the wavelength of incoming signals.

To find the optimum 3-D geometry of a multiple antenna array for maximizing the ECC, we proposed a novel fitness function to incorporate with a particle swarm optimization (PSO) algorithm for solving the resulting optimization problem. The (m,n)th element of spatial correlation matrices $\mathbf{R}_{tx}$ and $\mathbf{R}_{rx}$ are calculated by (2). With adoption of the Kronecker model, the covariance matrix of $\mathbf{H}$ equals $\mathbf{R}_{tx} \otimes \mathbf{R}_{rx}$, where $\otimes$ is a Kronecker product. However, for the considered optimization problem, we face a very complicated computational process to calculate exact form of (1) as the objective function. Therefore, we resort to another objective function with a reasonable computational complexity. The fitness function

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for the PSO optimization is introduced by finding the a closed-form upper bound of the ECC, (1), of a wireless communication system, which is given by

$$\text{Objective function} = f(\mathbf{P}) = \log\left(\sum_{k=0}^{N} k!\,\rho^k E_{tx,k} E_{rx,k}\right), \quad (3)$$

where $E_{tx,k} = \sum_{\boldsymbol{\alpha_k}} \lambda_{tx,\alpha_1}\lambda_{tx,\alpha_2} \dots \lambda_{tx,\alpha_k}$ and $E_{rx,k} = \sum_{\alpha_k} \lambda_{rx,\alpha_1}\lambda_{rx,\alpha_2} \dots \lambda_{rx,\alpha_k}$. Parameter $\boldsymbol{\alpha_k} = \{\alpha_1, \alpha_2, \dots, \alpha_k\}$ is any possible set of numbers $\alpha_k \in \{1,2,\dots,N\}$, $k = 1,2,\dots,N$. λ_{tx,α_1} and λ_{rx,α_1} represent the α_k th eigenvalues of the spatial correlation matrices $\mathbf{R}_{tx}$ and $\mathbf{R}_{rx}$, respectively. Besides, $\mathbf{P}$ represents the $3N \times 1$ vector containing the positions of the N array elements. The search space for the PSO optimization to find the optimum 3-D geometry is inside a 3-D sphere with radius given by D_{max}.

Moreover, there are no simulation results of using other techniques available in the literature for making comparison in the 3-D case. Based on (2), we then explore the characteristics of the SCF for several multiple antenna arrays with different array geometries. We found that a multiple antenna array with 3-D array configurations can reduce the magnitude of its SCF and hence maximize the ECC. Here, we present several simulation examples for illustration. In Fig.2, the example shows the results of using the proposed method for ECC maximization under a fixed D_{max}. The parameters used are as follows: $N_t = N_r = 6$, the means of the MAOA= 90^o, $\text{AS} = 3^o$, $\text{ES} = 5^o$, $D_{max} = 5\lambda$, where λ denotes the signal wavelength. The signal-to-noise ratio (SNR) is 10dB. We observe that the proposed method (the curve in black color of Fig.2) provides the best ECC performance for a multiple antenna array with a 3-D geometry. The corresponding optimum 3-D coordinates of each array elements are shown in Table 1. Although the ECC with a 2-D multiple antenna array (the curve in red color of Fig.2) can be improved by using the proposed method, the resulting ECC is very close to that with a uniform circular array (UCA). In Fig.3, the example shows the results of using the proposed method for ECC maximization under different values of D_{max}. The parameters used are as follows: $N_t = N_r = 6$, MAOA and MEOA both equal 90^o, $\text{AS} = 3^o$, $\text{ES} = 5^o$. The signal-to-noise ratio (SNR) is also 10dB. Again, we observe that the proposed method provides the best ECC performance (the curve in black color of Fig.3) for a multiple antenna array with an optimum 3-D geometry. The corresponding optimum 3-D coordinates of each array elements are shown in Table 2. Moreover, the ECC with a 2-D multiple antenna array can be significantly improved by using the proposed method as compared to that with a UCA. Our simulation results from these two examples have confirmed the validity and the effectiveness of the proposed method.

3DA PSO	E_1	E_2	E_3	E_4	E_5	E_6
x (in λ)	4.6606	4.6603	−0.0002	−0.0002	−4.6601	−4.6608
y (in λ)	1.6967	−1.6968	−4.6917	4.6921	1.6980	−1.6950
z (in λ)	−0.6322	0.6345	1.7285	−1.7275	−0.6327	0.6354

Table 1. The array element positions after performing the optimization process corresponding to Fig. 2, where E_i designates the ith array element, $i = 1,2,\dots,6$.

3DA PSO	E_1	E_2	E_3	E_4	E_5	E_6
x (in λ)	4.9983	3. 0331	2.7312	−2.7019	−3.0249	−4.9980
y (in λ)	0.0012	0.0036	0.0045	−0.0073	0.0028	0.0104
z (in λ)	−0.1297	3.9749	−4.1882	4.2071	−3.9812	0.1399

Table 2. The array element positions after performing the optimization process corresponding to Fig. 3, where E_i designates the ith array element, $i = 1,2,\dots,6$.

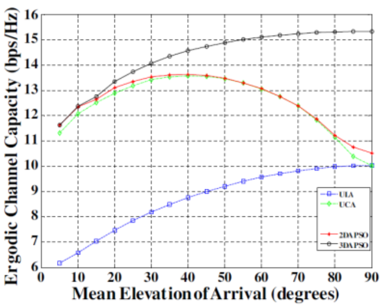

Fig. 2 The ECC versus MEOA

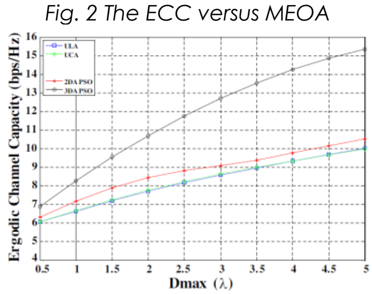

Fig. 3 The ECC versus D_{max}

References

[1] Ju-Hong Lee and C.-C. Cheng, "Spatial Correlation of Multiple Antenna Arrays in Wireless Communication Systems," Progress in Electromagnetics Research, *Vol. 132, pp. 347-368, Oct. 2012.*

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Activities

2013 Taiwan Spring School on Information Theory and Communications

The 2013 Taiwan Spring School on Information Theory and Communications was organized and hosted by Prof. Hsuan-Jung Su (Graduate Institute of Communication Engineering, National Taiwan University) and Dr. Chia-Han Lee (Academia Sinica), and held at the Barry Lam Hall of the College of EECS, National Taiwan University, Taipei, Taiwan, ROC, on Saturday, March 9, 2013. The Spring School provided an opportunity for Taiwanese Ph.D. students and their advisors from different universities to meet and interact on various subjects in the fields of Information Theory and Communications. This was the second time that the School had been held since 2011. It attracted a total of 60 participants this year. Fifteen Ph.D. students presented their current status of research in four sessions focusing on MIMO Detection and Channel Estimation, Error-Correcting Codes and Coded-System, Security and Multicasting, and Spectrum Sharing and Dynamic Bandwidth Allocation, respectively, and received valuable feedback and comments. After all the Ph.D. students had made brief oral presentations, a joint poster session was also held (at a nice art gallery at the Barry Lam Hall) for the presenters to further exchange research ideas and results with the other participants in a casual atmosphere. The Spring School not only offered opportunities for practicing English presentations to graduate students, who would find them beneficial in future study and work, but also provided a platform for information exchange and intercampus collaboration for the participants. Based on the audience's votes, two best presenters were selected. The Best Presentation Awards were presented by Prof. Ying Li (Chair of IEEE Information Theory Society, Taipei Chapter) and Prof. Mao-Ching Chiu (Chair of IEEE Communications Society, Tainan Chapter), respectively, to the awardees Mr. Chih-Yu Wang (National Taiwan University, Advisor: Prof. Hung-Yu Wei) and Mr. Chieh-Yao Chang (National Chiao Tung University, Advisor: Prof. Carrson C. Fung) before the banquet.

Group photo

Third Smart Living Seed-Teacher Training Camp and Achievements Conference

In the past decades, Taiwan has built up a very competitive OEM/ODM-oriented industry and achieved the so-called Taiwan Economic Miracle. However, as we now face the effects of globalization and of competition from countries such as BRICS, Taiwan has to rethink her future industry development strategy. Among the many new challenges ahead, those that call for urgent assessment include issues related to the country's aging society, extremely low birth rate, and environmental problems related to global warming. Unlike the development in the past, such future industry must be developed with consideration given to the humanities, environmental sustainability, cultural uniqueness, and social fairness.

The Executive Speech of Deputy Director of Department of Information and Technology Education, Ministry of Education.

PIs of Creative and Revolutionary Education Taiwan Innovation Consortium explained their achievements to Deputy Director of Department of Information and Technology Education, Ministry of Education.

To this end, the Talent Cultivation Program for Smart Living Industry was started 2 years ago in NTU, with official sponsorship from the Ministry of Education (MOE), and has a mission in cultivating university students and teachers through interdisciplinary

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Activities *(continued from page 6)*

training and, thus, equipping them with the ability to fit the future needs of emerging industry, needs that relate not only to technology but also to social, cultural and environmental issues. As a bridge between MOE and the entire program, the Program Office located in NTU Telecommunication Research Center is responsible for program orientation, planning, organizing, performance evaluation, and coordinating the whole program including all of the subprograms. To cultivate smart living talent, their main tasks include: 1. Developing Innovative Courses for professional skill development and hand-on training; 2. Building up International Relationship; and 3. Promotion Activities: organizing supplemental activities for inner collaboration and public participation. Currently, the program office of this Smart Living Talent Cultivation Program is leaded by Prof. Zsehong Tsai of NTU GICE.

On March 9, 2013, the annual conference of this program, called the Third Smart Living Seed-Teacher Training Camp and Achievements Conference, is held in the international conference hall in the Tsai Lecture Hall, National Taiwan University. The co-organizers include Innovation Consortium for Smart Living, Communication Research Center of National Taiwan University, and Taiwan Smart Living Space Association.

In this event, Excellent Professional Specialist Lecturers and Instructors of Excellent Courses were honored officially with various awards. All PIs, course lecturers in this program and the industrial partners, including III, Chunghwa Telecom, BenQ, etc. are invited for exhibitions and panel discussions. And the total number of participants in this one-day event is more than 170.

TEMIAC Technical Forum-Challenges for Future Applications and Opportunities of Next-Generation Mobile Communications Transmission Technology

With the popularity of smart mobile devices, bandwidth requirements from customers rapidly raise. The operators are trying to find a way to increase the efficiency of data transfer in a limited number of base stations while facing such a huge network usage, which becomes the main developing objective of the communication technology in recent years. This quarterly technical forum is held together by Taiwan Electromagnetic Industry-Academia Consortium (TEMIAC), Graduate Institute of Communication Engineering (GICE) of National Taiwan University, and Communication Research Center (CRC) of National Taiwan University. Experts from industries and academia are invited and there are approximately one hundred people to attend this conference (40% from industries and 60% from academia). The main issue discussed in this conference is about "Challenges for Future Applications and Opportunities of Next-Generation Mobile Communications Transmission Technology". A total of five keynote speeches and a panel discussion are in the program. The topics of the speeches include antenna design, power amplifier design, and the development of the architecture of the wireless communication. These speakers are from GICE of National Taiwan University, network operators of Taiwan (Chunghwa Telecom and Taiwan Mobile), and Institute for Information Industry. At first, they share the latest development of the domestic technologies, which is suitable for the application of next-generation mobile devices. Subsequently, the panel discussion talks about the possibilities and prospects of these technologies to become the core technologies. The other purpose of this conference is to provide an exchanging platform to mitigate the gap between the industry and academia. By sharing the latest status of the technology developments during this conference, the goal is achieved to enhance Taiwan's competitiveness in next-generation communication industry.

About 100 Experts from industry and academia are invited to attend this conference.

Panel discussion (from left to right) Dr. Pao-Chung Ho, Institute for Information Industry. Mr. Tom Koh, Taiwan Mobile. Mr. Mu-Piao Shih, Chunghwa Telecom Co., Ltd. Prof. Char-Dir Chung, NTUEE&GICE. Prof. Zsehong Tsai, NTUEE&GICE.

Invited Talk

From Compressive Sensing to Super-Resolution

Lecturer: Prof. Emmanuel Candes

On March 27th, Professor Emmanuel Candès from Stanford University presented several innovative results in compressive sensing with its applications in various fields. The applications like magnetic resonance imaging (MRI) or high-resolution microscopy have some physical limits such as number of sensors, slow speed of data collection, and expensive measurements. Motivated by these challenges, he as well as his fellow researchers has developed compressive sensing as a novel approach to recover the images, video sequences or data matrix.

Beginning by introducing discrete Fourier transform and early results by C., Romberg and Tao in 2004, Professor Candès indicated that compressive sensing has shown that super-resolved signals can be obtained from just a few sensors or data bits. Moreover, simple acquisition can be achieved by following numerical optimization.

Later on, the talk covered the fundamental results of compressive sensing, which provided a framework for new measurement strategies. It is proved that if the probability distribution obeys a simple incoherence and isotropy property, one can faithfully recover approximately sparse signals from a minimal number of noisy measurements. The theory thereafter implies the robust property to noise and other imperfections. The performance improvement is crucial in fast MRI applications. The technique can also be applied to analog-to-digital conversion, microscopy, holography, computer tomography, and hyperspectral imaging, etc..

Prof. Candès continued to explain the term "super-resolution", which is used in different contexts mainly to design techniques for enhancing resolution of a sensing system. Moreover, Prof. Candès described his latest work on the recovery of a superposition of point sources from noisy band-limited data. At the end of the talk, he encouraged young researchers to attend seminars in other research fields to broaden the horizon.

Prof. Luca Daniel
Massachusetts Institute of Technology

Topic: Simulation, Modeling and Optimization for Complex Systems

Prof. Jin-Fa Lee
The Ohio State University

Topic: Next Generation Computer Simulations for Multi-Physics and Multi-Scale Engineering Applications

Dr. Masataka Goto
National Institute of Advanced Industrial Science and Technology (AIST), Japan
Topic: Frontiers of Music Technologies: Active Music Listening Interfaces and Singing Synthesis Systems

Prof. J. C. Chiao
University of Texas – Arlington, USA

Topic: Implantable wireless medical devices and systems

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