National Taiwan University
Graduate Institute of Communication Engineering Newsletter

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In this issue

Upcoming Events:

April 25
Dr. Yu-Chee Tseng Visit
Associate Dean, College of Computer Science, National Chiao Tung University

April 27
Dr. Stephane Mallat Visit
Applied Mathematics Department, École Polytechique, Paris, France

Technology Developed in GICE

Professor Emeritus Chun-Hsiung Chen's Contributions on Variational Electromagnetics and the Global Developments of Electromagnetic Waves

from Electromagnetics Group

Established right after World War II, the Electromagnetic Wave Group was originally named as the Radio Wave Research Laboratory. It actively involved in researches on ionosphere wave propagation. The EM group was later well recognized for its pioneering researches on variational electromagnetics anchored by Prof. Chun-Hsiung Chen in 1980's, which later laid the cornerstone of some today's commercial software, especially HFSS.

Professor Emeritus C.-H. Chen joined the faculty of the Department of Electrical Engineering as an Instructor (1963-68), an Associate Professor (1968-72), a Professor (1972-2007), and Chairman of the Department (1982-85). Prof. Chen's areas of interest include microwave circuit analysis and computational electromagnetics. In the early 80s, the development of satellite communication has completely replaced the role of ionosphere in long-distance communication. During that time, it was the start of computing using the foundation of Integral Equation, and which has many limitations on material composition and complex construction in shapes.

Prof. Chen foresaw that using finite element in civil and mechanical field can handle general structures and started a series of research on variational electromagnetics. His team also published a number of papers on its advantages, and became international pioneer in this area. This method was later supported by the global industry to develop the famous business software HFSS. This becomes an indispensible tool in analyzing electromagnetic fields in practically structures, as well as the key of rapid development in electrical and electronic engineering globally. Prof. Chen also awarded IEEE Fellow in 1996 "for contributions to the development of variational and other numerical methods applied to coplanar waveguides and various other structures."

Besides his research achievements, Prof. Chen also set the "Thesis Points System" during his chairmanship in 1982-1985. It specifically requires the doctoral students to publish their papers on international journals. This evokes other universities to adopt the same method, and further advances the research level in Taiwan. In the case of SCI paper number, Taiwan in 1995 has been ranked from #40 to #19 worldwide after a decade's efforts. Prof. Chen's visions and key decisions had truly set the milestone in Taiwan's academic development.

Thanks for Prof Chen's endeavor, the EM Group maintains world-class experimental facilities that have been upgraded over the years through project funding supported by government and industry. His contributions certainly built the solid foundation of the EM Group.

Technology

On Cooperative Strategies in Wireless Relay Networks

from Communication and Signal Processing Group

Recently, the concept of multi-hop relaying has gained much attention in the context of centralized wireless relay networks (WRNs). Relay stations (RSs) are believed to be a cost-effective option for increasing network coverage and enhancing system throughput in wireless access networks In a WRN, the base station (BS) centrally controls the resource allocations and transmission schemes of all RSs within the cell. Consequently, multiple RSs can be coordinated by the BS to form a *virtual antenna array*. The spatial diversity of RSs together with space-time codes can significantly improve the quality of the transmitted signal thereby enhancing the channel capacity. This transmission scheme is referred to as *cooperative transmission* in the literature. An example of RS cooperation in a WRN is shown in Fig. 1.

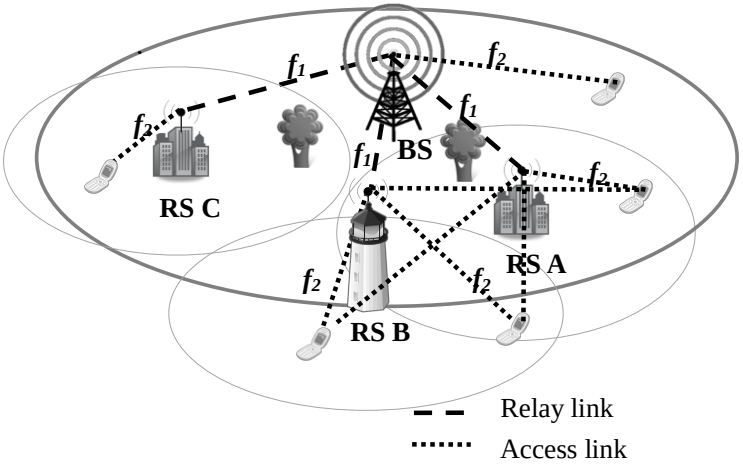

Fig 1. An example of RS cooperation in a wireless relay network.

The fact that many nodes can cooperate to transmit data induces the following issues: What is the impact of node cooperation on the network? How do we determine the partners for each node to cooperate with such that the network performance can be optimized? Aiming at answering these questions in the context of WRNs, we first study how the behavior of RS cooperation affects the performance of WRNs.

In this work, we adopt a two-hop TDMA system model for analyzing the relay cooperation problem. The link between the cooperating RSs and the target MS modeled by a virtual multiple-input-single-output (MISO) channel. Since the diversity gain achieved by RS cooperation can result in an increase of transmission range, in a multi-rate network, this means that more MSs could be covered by the RSs with higher transmission rates. Consequently, by carefully manipulating the cooperation of relay stations, the downstream throughput of the entire system can be increased.

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GICE Honors

Professor
Tzong-Lin Wu

Outstanding Research Award of National Science Council

Message from the Director

Kwang-Cheng Chen

Professor &
GICE Director

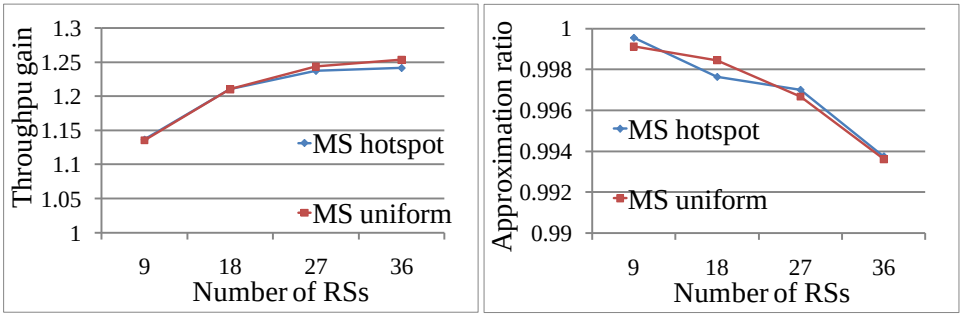
It has been quickly over a year since the quarterly GICE Newsletter launched. We are happy to share a lot of exciting technology breakthroughs from GICE research, along with honors from GICE faculty and students. At this milestone getting into the second year, we wish you find GICE Newsletter more informative and helpful.

Technology (continued from page 2)

To analyze which relay stations should cooperate such that the system performance could be optimized, we mathematically formulate the Cooperative Relay station Cooperation Problem (CRCP) via a binary programming model. Since the objective involves a non-linear function, this type of problem is generally NP-hard. To efficiently derive sub-optimal solutions, we propose an *iterative local search with optional random restart* (*ILS-ORR*) algorithm that combines the advantages of both local search and random search. There are two phases in the *ILS-ORR* algorithm: the iterative local search phase and the optional random restart phase. In the first phase, we perform local search from the current solution. Whenever reaching a local optimum, we will evaluate if the solution is good enough by comparing to a performance upper-bound. If not, then we will record the current best solution and then enter the second phase, whose purpose is to rescue the current solution from being trapped in a local optimum. The way to achieve this is to perform random jump from current local optimum solution. After the second phase, we return to the first phase, and iteratively repeat the whole process until any local solution reaches a pre-determined performance bound.

To evaluate how much the cooperative behavior of relay stations benefits network performances as well as the efficiency of the proposed *ILS-ORR* algorithm, we perform a series of computer simulations. Our performance metrics include the throughput gain, the approximation ratio, and handover probability. We also study how the RS placement impacts the throughput gain of *ILS-ORR*. In our simulation environment, there are a variable number of RSs deployed as well as 400 mobile stations populated in a BS cell whose radius is equal to 1.5 km. There are two possible distributions for the locations of the mobile stations: random or distributed in hotspots. In Fig. 2(a), the results show that for both MS distributions, the throughput gain increases with the number of RSs because more RSs deployed means a higher possibility for RS cooperation. Nevertheless, the throughput gain is eventually saturated because when there are many RSs, the throughput is high enough even without RS clustering. The approximation ratio shown in Fig. 2 (b) is the ratio of solution qualities between the solution derived by the ILS-ORR algorithm to an upper-bound of the optimal solutions. The fact that these ratios are very close to one verifies that the ILS-ORR algorithm can achieves near-optimal solutions. In Fig. 3(a), we show that the convergence time of ILS-ORR scales linearly with the number of RSs, which makes it applicable to realistic WRNs. In Fig. 3(b), the simulation results also suggest that with RS cooperation, the handover (HO) probabilities of the mobile stations can also be reduced, especially when mobile stations are distributed in hotspots. Finally, in Fig. 4, we show that by strategic placement of RSs, the throughput gain from cooperative transmission of relay stations can be further enhanced.

To sum up, we analyze the impact of RS cooperation on the downstream throughput of WRNs and present mathematical formulations of the throughput maximization RS cooperation problem. An iterative local search algorithm is proposed. According to our simulation results, the proposed algorithm yields near-optimal solution with only linear-time complexity Moreover, simulation results also show that i) throughput gain from cooperation is proportional to the density of deployed RSs, ii) The handover probability of MSs can also be reduced with RS cooperation, and iii) the placement of the RSs is critical to the performance of RS cooperation. Our observations and the proposed *ILS-ORR* algorithm can serve as guidelines for planning of practical wireless relay networks, including the emerging IEEE 802.16j (WiMAX) networks.



(a) (b)

Fig. 2. (a) Throughput gain (b) Approximation ratio

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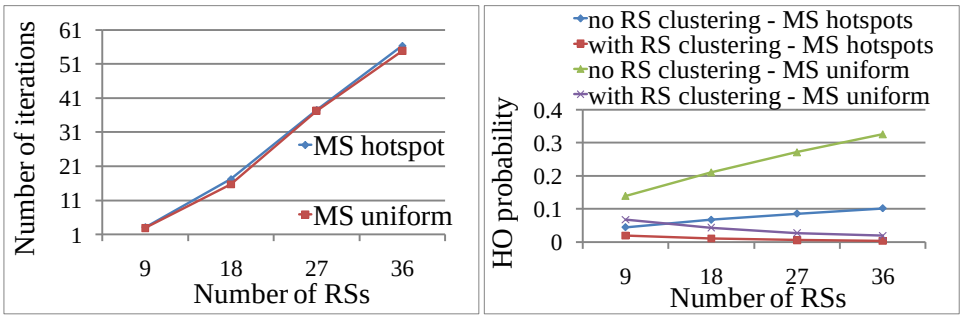

(a) (b)

Fig. 3. (a) Convergence time (b) Handover probability

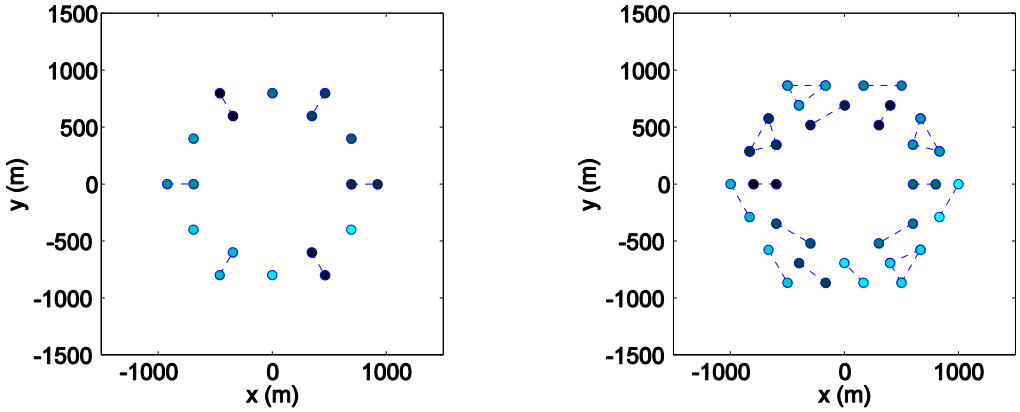

Fig. 4. Strategic RS placements. Left: 18 RSs, two-tier topology. Throughput gain = 1.3596. Right: 36 RSs, three-tier topology, throughput gain = 1.476

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Co-author of the article: Hsiao-Chen Lu, PhD Candidate of NTU GICE

High Efficiency Pulse-Modulated Polar Transmitter for Cellular Phones

from Electromagnetics Group

The RF power amplifier is a crucial component in wireless communication devices. It is especially true for the overwhelming cellular phones because the power amplifier needs to meet the stringent linearity specifications while delivering large signal power efficiently. The technical challenge of power amplifier increases along with the evolution of cellular communication. A series of power amplifier technology and patents have been developed by Prof. Yi-Jan Emery Chen's research team to return the call for high efficiency linear amplification of mobile communication signals.

The envelope elimination and restoration (EER) technique is a method that uses highly nonlinear, but highly efficient radio frequency (RF) power amplifiers (PAs) as a modulator to restore the amplitude on a phase modulated input signal. A modified EER architecture has recently been reported, which uses a switch or mixer to modulate the input signal of the RF PA. The main benefit of this approach is the removal of the envelope amplifier, which is hard to design with wide bandwidth and high output power level. The pulse modulation of the input signal of a polar transmitter can be realized using pulse-width modulation (PWM). With the advancement of modern digital CMOS technology, it is now possible to implement DPWM using high clock rate digital counters. If a digital counter runs at a clock rate of f_{clk} and counts to a maximum of N, the counter can then generate a PWM signal with sampling frequency, f_{PWM}, of f_{clk}/N, which has $N+1$ different pulse widths. For pulse modulated polar transmitters, it is

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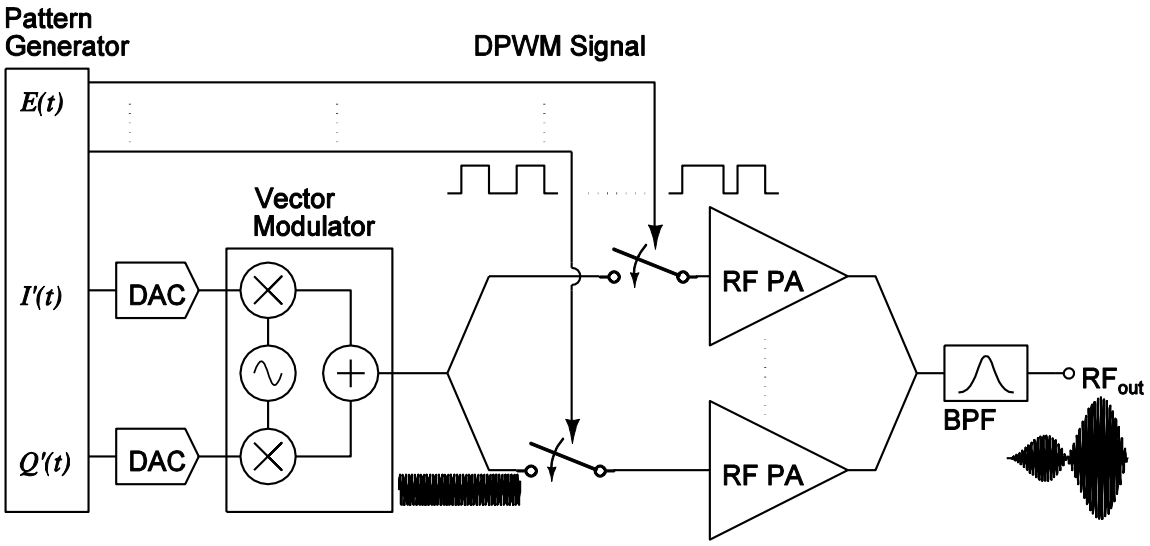

Fig. 1. Schematic diagram of a dual-level pulse modulated polar transmitter.

desirable to have a high f_{PWM} such that out-of-band emissions can be sufficiently filtered by external BPF at the output of the RF PA. For a constant f_{clk}, a higher f_{PWM} leads to a lower N and effectively reduces the resolution of the envelope signal. A lower resolution will lead to a higher noise level, which may cause the polar transmitter to fail certain spurious emission requirements.

A multi-level pulse modulated polar transmitter is proposed. The basic method of implementation is shown in Fig. 1. With multiple RF PAs in parallel, each controlled by a DPWM signal, the effective number of different pulse widths is increased from $N+1$ to $M \cdot N+1$, where M is the number of PAs. This can be achieved while the clock frequency, f_{clk}, and the PWM sampling frequency, f_{PWM}, can remain unchanged. Therefore, by doubling the number of RF PAs using this method, the effective resolution can be increased by approximately a factor of two, which is the same as increasing one bit in the resolution of the envelope signal. An example of a dual-level DPWM signal is shown in Fig. 2.

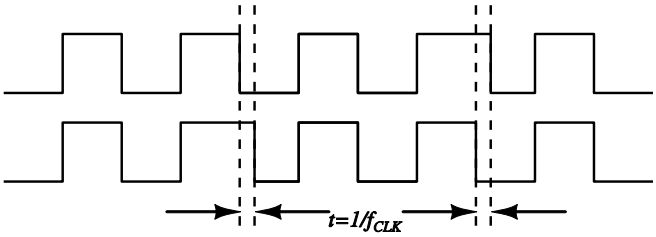

Fig. 2. Example of a dual-level DPWM signal.

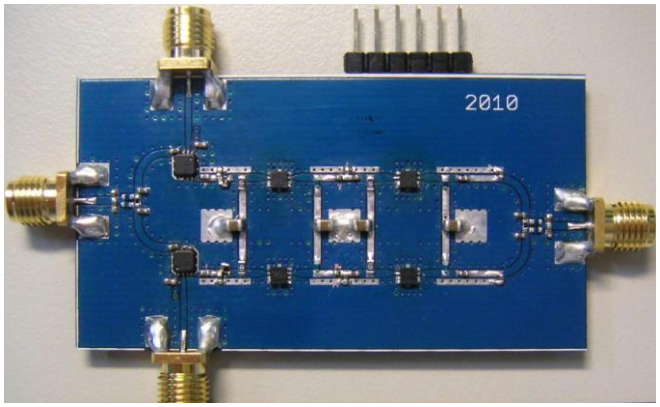

Fig. 3. Prototype of the dual-level pulse modulated polar transmitter.

To verify the proposed polar transmitter architecture, a prototype system was implemented as shown in Fig. 3. A pair of RF power amplifiers using commercially available enhancement-mode pseudomorphic high electron mobility transistors (PHEMT) biased in the class-C region was designed. A pair of commercially available switches that is internally matched to 50 ohm was connected to the input of the matched pair of RF PAs and was used to modulate the constant envelope RF input signal. The input phase signal was split with a Wilkinson power divider and the output pulse modulated signals were combined with a Wilkinson power combiner. An 836.5 MHz CDMA2000 1X signal was used to test the implemented polar transmitter system. A single-level DPWM signal and a dual-level DPWM signal were generated with a maximum counter count of N = 8. The proposed polar transmitter was measured at an output power level of 24.5 dBm and achieved a power-added efficiency of 40.2% for both signals. The adjacent channel power ratio (ACPR1) and alternate channel power ratio (ACPR2) measurements were made using a spectrum analyzer and seen to meet

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Technology (continued from page 5)

the specification with the use of the proposed technique. The output spectrums for both signals are compared in Fig. 4. Comparing the ACPR2 measurement, it was improved by 4.5 dB with the use of this architecture.

Most wide bandwidth EER transmitters or polar transmitters previously reported required the use of digital pre-distortion to meet certain linearity requirements because of non-ideal envelope amplification. However, the proposed polar transmitter was able to pass the stringent ACPR requirements without the use of digital pre-distortion. Another benefit of using this architecture is the synchronization of the envelope and phase paths. Compared to conventional EER implementations that have slow envelope paths, which require long delays in the phase path using digital memory or a linear-phase filter, the implementation of the pulse modulated polar transmitter is less complex. The filtered spectrum was able to pass the spurious emission requirement for band class 0 (cellular band) of the CDMA2000 standard.

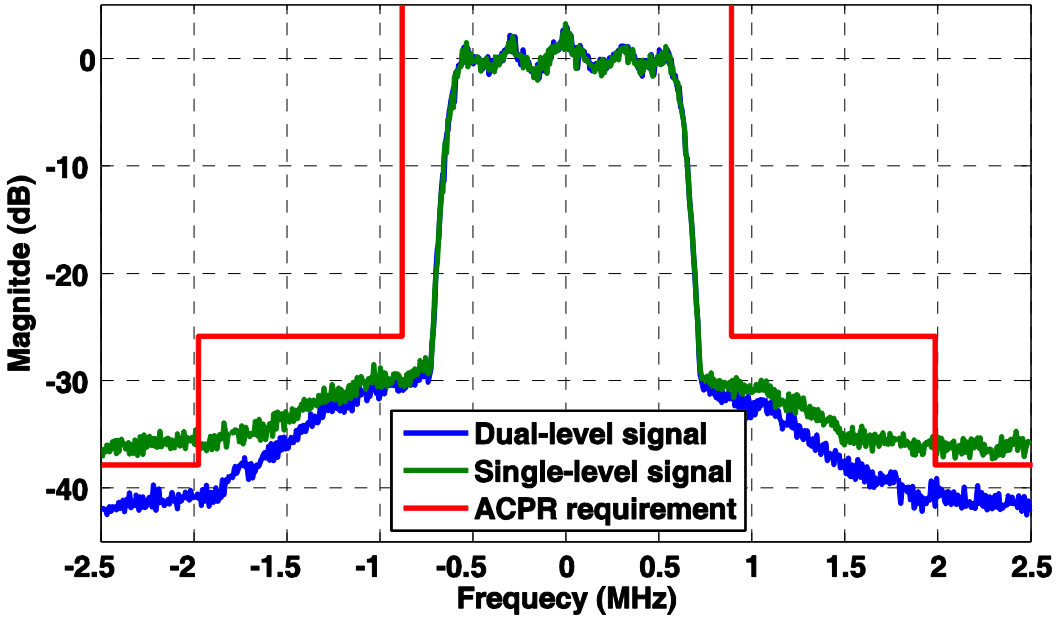

Fig. 4. Comparison of the output spectrums of the pulse modulated polar transmitter using a dual-level signal and a single level signal centered at 836.5 MHz.

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Activity

GICE Professors Participated in the Exhibition of NTU 2011 Azalea Festival

The annual NTU Azalea Festival was held on March this year. One of the celebration activities was the "Innovative Science Creates New Civilization Exhibition" which displayed the fruitful research achievements of the professors of College of Electronic Engineering and Computer Science of NTU. Some GICE professors' recent researches were introduced in the exhibition with the topics of Music& Computer Technology (Prof. Shyh-Kang Jeng), Antenna (Prof. Shih-Yuan Chen), Secure Communications (Prof. Ping-Cheng Yeh) and Millimeter Wave Application (Prof. Huei Wang).

Research Posters displayed in the "Innovative Science Creates New Civilization Exhibition"

Activity

Grand Opening Ceremony of Taiwan Electromagnetic Industry-Academia Consortium

The grand opening ceremony of Taiwan Electromagnetic Industry-Academia Consortium was held on Dec. 17, 2010, established by convener Prof. Ruey-Beei Wu with support of Dept. of Electrical Engineering and Communication Research Center. In the ceremony, Minister without Portfolio of Executive Yuan Mr. Jin-fu Chang, NSC Minister Lou-Chuang Lee, NCTU President Chung-Yu Wu, NTUST President Shi-Shuenn Chen, NTUT President Tsu-Tian Lee, and NTU President Si-Chen Lee all attended to celebrate the establishment of the Consortium. Meanwhile, 24 representatives from the industry and more than 40 professors from eight universities also participated to support the alliance.

Taiwan Electromagnetic Industry-Academia Consortium is the only consortium between the industry and academia in the electromagnetic field in Taiwan. It is originated by electromagnetic teams of eight universities, including NTU, NCTU, NCU, NTUST, NTUT, YZU, CCU, and NSYSU. The Consortium also quickly gained the support from the industry, including companies TSMC, MediaTek, Ralink, Garmin, WNC, ASUS, Quanta, Intel, Himax, MTI, Realtek, and Chunghwa Telecom.

NTU President Si-Chen Lee indicated that Maxwell's equation in 1864 still influences human's technology today, which showed the significance of Electromagnetics. Responding to a brain drain of the electromagnetic field in recent years, President Lee affirmed convener Prof. Wu for taking the responsibility to establish the industry-academia platform. Lee also thanked the companies who are willing to participate in this program to provide a better academic environment in the electromagnetic field.

Convener Prof. Wu expressed that through the establishment of this consortium, this platform can promote the development of electromagnetic technology and innovation. In addition, he hopes this consortium can attract more outstanding talents, promote innovative research, preempt industry-academia barriers, and stimulate the cutting-edge technologies in electromagnetic area.

The grand opening ceremony also invited Mr. C. T. You, ITRI Vice Director of Industrial Economics & Knowledge Center (IEK), to give a presentation of "Electromagnetics in Future Daily Applications and Industrial Trends." There were also research demos from six universities (NTU, NCTU, NCT, NTUST, NTUT, and YZU) outside the venue. Through the demos by professors and students, there is no doubt that it attracted representatives from each company to discuss the interested issues bilaterally. These not only successfully achieved the exchange and cooperation between industry and academia, but also built a milestone for Taiwan's cross-university industry-academia cooperation.

Grand Opening Ceremony of Taiwan Electromagnetic Industry-Academia Consortium. (From left to right) Convener Prof. Ruey-Beei Wu, NCTU President Chung-Yu Wu, NTU President Si-Chen Lee, NSC Minister Lou-Chuang Lee, Minister without Portfolio of Executive Yuan Mr. Jin-fu Chang, NTUST President Shi-Shuenn Chen, and NTUT President Tsu-Tian Lee.

Activities

Invited Short Courses on Network Coding

GICE invited Prof. Shuo-Yen Robert Li from The Chinese University of Hong Kong to present a series of courses about network coding on Dec. 20 and Dec. 21, 2010. Prof. Li is one of the creators of "Network Coding Theory." At present he is the Chair Professor of Information Engineering and Co-Director of Institute of Network Coding of CUHK.

In Prof. Li's Network Coding- A dialogue between math and engineering series, four lectures were given, including Linear Network Coding- a Paradigm Shift in Data Transport, Convolutional Network Coding, Network Coding Theory via Commutative Algebra, and Construction of Optimal Codes Over Cyclic Networks.

Attracted by Prof. Li's famous research and theory, over a hundred professors and students from NTU and other universities participated the courses over this two-day program.

Short Courses on Network Coding by Prof. Shuo-Yen Robert Li of The Chinese University of Hong Kong

Corner of Student News

by Yu-Ting Lin

Supélec is the abbreviation of "Supérieuse Electricité", which is one of the Grande Ecoles d'Ingenieur in France, and it is always in third ranking in Telecom and Information in France. Thanks to my director professor K.C Chen so that I can visit here to fulfill my dream. It has been six months since I came to this beautiful campus, which locates 50 km away from the center of Paris.

I am here doing my first year study with 17 different classmates from different countries. Most of them are from Europe and Africa. We speak two languages English and French to communicate with each other and we have an abundant schedule every day from information theory, coding theory to traditional communication techniques.

Being different from the students of NTU, the students here have to find a research-oriented internship at the end of their studying. I think that is a really good opportunity to combine our learning with reality world, and the college will also provide some interns in the companies like Orange, Alcatel and Thales. Some of my friends are really enthusiastic at the internships and some of them are preparing for applying a PhD in France for example to apply a PhD in the Alcatel-Lucent Flexible Radio Lab. It seems that everyone has its direction and this is very cool to study in this kind of environment where we can share the ideas with the others.

Due to the distance from Paris, most of time I stay in the campus and in the weekend I have to do some shopping in Paris. The Life here is so simple which is different from the life in Taipei. I think is really suitable for the research job. Just few days ago, the first snow in this winter came. The scenery is so beautiful especially the scenery in the forest. I hope I can do my research well here and I am grateful to NTU to give me the chance and wish each of you good luck.

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