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Graduate Institute of Communication Engineering, National Taiwan University

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In this issue

Technology Developed in GICE

Interactive Interference Management in Bursty Wireless Networks

from Communication and Signal Processing Group

Introduction

Interference has become the major barrier against efficient utilization of limited spectrum in modern wireless networks. For wireless networks, the simplest information theoretic model for studying interference is the two-user Gaussian interference channel (IC), in which it is assumed that the transmitted signal from one transmitter always interferes with the receiver of the other user. Under this potentially conservative modeling assumption, the capacity region is characterized to within 1 bit/s/Hz [1], which sheds light on how to manage interference in the high SNR regime.

In many realistic scenarios, however, interference could be intermittent owing to the distributed medium access control mechanisms and/or the decentralized networking protocols across different users. For example, consider an OFDM-based wireless system; where two neighboring access points (AP's) lack coordination in allocation of subcarriers to the users they serve. Since each cell has full frequency reuse, from time to time a cell-boundary user served by one AP is faced with interference caused by some other cell-boundary user served by the other AP. If these two AP's allocate the same frequency band to the users they serve, they interfere with each other. If not, they form two point-to-point interference-free links and are free of interference.

Hence in the physical layer, it may be too pessimistic to assume that interference is always present. In principle harnessing such intermittence/burstiness could increase users' data rates. A natural way to harness such intermittence is the degraded-message-set approach proposed in [2], where an opportunistic message can be decoded in addition to the original message when the interference is not present. The degraded-message-set approach does not require any feedback from the receivers. In most wireless systems, however, feedback is an available resource and potentially

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GICE Honors

Prof. Hung-Yu Wei

The Chinese institute of Electrical Engineering 「2014 Excellent Young Engineering Award」

Prof. Tian-Wei Huang

IEEE MTT-S Distinguished Microwave Lecturer

Prof. Soo-chang Pei

「IEEE Life Fellow」

Message from the Director

Tzong-Lin Wu

Professor & GICE Director

As time goes by, GICE insist on sharing you with two excellent research outcome offered by Prof. I-Hsiang Wang and Prof. Shau-Gang Mao. Besides, this periodical shows a good sign in the beginning of 2015.

First of all, In order to attract foreign students and to broaden NTU GICE students' worldview, GICE signed a double degree agreement with a prestigious institute of France (INPT-ENSEEIHT) which is a milestone for GICE international exchange program.

Another exciting event to share is the opening of 'NTU High-Speed RF and mm-Wave Technology Center', which will boost the 5G research in GICE in next few years. We sincerely hope that would bring abundant benefits to GICE.

Wish you enjoy the latest Newsletter and continue to witness the great growth of NTU GICE.

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can be utilized to manage interference and/or exploit the intermittence.

In [4], we explored the benefit of feedback for physical layer interference management in wireless networks with intermittent/bursty interference. To understand how to harness such intermittence with feedback, we investigated a two-user bursty interference channel (IC), where the presence of interference is governed by a Bernoulli random state, as depicted in Figure 1.

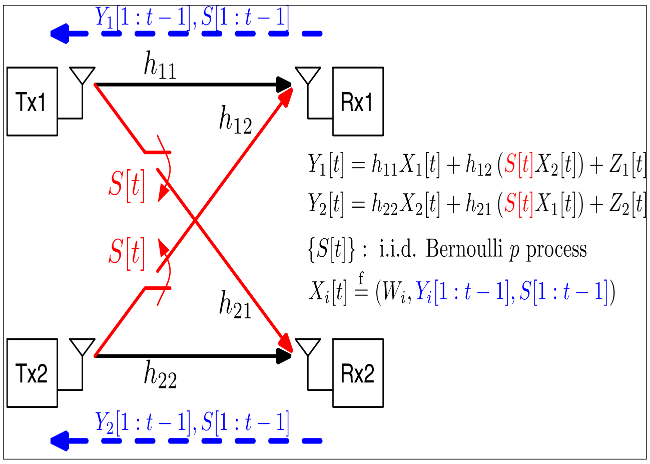

Figure 1. Two-user bursty interference channel

To harness the intermittence of interference, we proposed an adaptive coding scheme exploiting feedback either for refining the previous interfered reception or for relaying additional information to the legitimate receiver of the other user. Matching outer bounds are derived by novel techniques that take the effect of delayed state information into account. As a result, we characterized the generalized degrees of freedom of the system completely, which accounts for the high SNR approximate capacity per user, depicted in Figure 2.

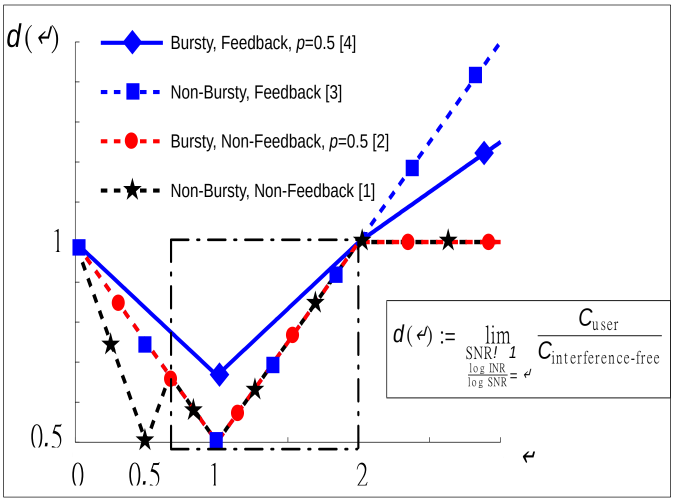

Figure 2. Comparison of generalized degrees of freedom

Due to space constraint, we refer the interested readers to [4] for more details. In the rest of this article, we focus on the degrees of freedom of the two-user bursty IC, and demonstrate the synergetic benefit of feedback in managing intermittent interference.

Scenario and Baselines

We assume that during each time slot, the system will have interference with probability 50% (p = 1/2), and whether interference will occur or not in the current time slot is completely independent of other time slots.

We focus on the high-SNR asymptotic system capacity, that is, the sum degrees of freedom (DoF) of this channel. Intuitively speaking, the sum DoF stands for the total number of data streams the system can reliably support. It is useful to bear in mind that the increase in DoF implies significant improvement in system capacity.

Consider two baseline cases: Non-bursty IC with and without Feedback, and Bursty IC without Feedback. It turns out that in both cases, sum DoF is equal to 1 for the entire system [1–3]. Hence,

[1] Feedback cannot increase the DoF of non-bursty IC.

[2] Harnessing burstiness without feedback cannot increase the DoF of bursty IC.

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Main Question: A natural question arises: can feedback increase the DoF of the bursty IC, by harnessing the intermittence of interference and providing side information about the previously encountered interference? At first glance, the answer seems to be the negative due to the above two baselines.

Harnessing Intermittent Interference with Feedback

In the following, however, we shall see that a very simple scheme is able to boost up the total DoF from 1 to 4/3. This suggests that feedback can provide synergic benefit in managing intermittent interference.

The following is a simplified version of that in [X]. It comprises of two phases:

Phase Fresh (F): Tx *i* sends fresh information symbol X_i, $i = 1, 2$.

Initially Tx *i* sends out a fresh information symbol X_i that carries 1 DoF for user *i*, $i = 1,2$. If there is no interference, Rx *i* can decode the desired symbol X_i, and both Tx's remain in Phase F in the next time slot. If there is interference, Rx *i* receives a linear combination of X_1 and X_2, and hence cannot decode the desired symbol X_i. Both Tx's learn it through feedback, and accordingly transit to Phase R described as follows.

Phase Retransmit (R): Tx *i* retransmits the previously sent symbol X_i, $i = 1, 2$.

If there is no interference, Rxi can decode the desired symbol X_i, $i = 1, 2$, and both Tx's transit back to Phase F in the next time slot. If there is interference, on the other hand, Rx *i* receives another linear combination of X_1 and X_2, and is able to decode both X_1 and X_2. Hence, regardless of the presence of interference, each Rx can decode its own 1-DoF data stream in the end of Phase R and transits back to Phase F in the next time slot.

Hence we can derive the two-state Markov chain that governs the transition of transmission phases, which has steady-state distribution $\pi(F) = 2/3$, $\pi(R) = 1/3$. Then we derive its achievable sum DoF = $2/3\times1/2\times2 + 1/3\times1\times2 = 4/3$.

Conclusions

In this article, a new concept is introduced into the information theoretic investigation on the capacity of wireless networks: network connectivity, such as interference, interaction, etc., can be bursty and intermittent. With this new concept, not only can the existing coding schemes be redesigned and improved, but some new results are also revealed. One of the key innovations along this line is the surprising fact below:

One-bit feedback can provide unbounded capacity increase.

To sum up, feedback is more useful in managing intermittent interference than static one, which implies that interaction is a promising candidate for interference management in more dynamical systems.

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High-Power and High-Efficiency RF Rectifiers Using Series and Parallel Power Dividing Networks and Their Applications to Wirelessly Powered Devices

from Electromagnetics Group

With the rapid developments of mobile devices and sensor networks, wireless power transmission has become increasingly attractive to free a variety of electronic systems from power cords and batteries [1]. Electromagnetic induction [2] and LC resonance [3] are the widely accepted technologies of wireless power transformation, offering high efficiency with large Tx and Rx coils over a small distance with respect to wavelength.

Conventional RF rectifiers using silicon-based Schottky diodes are usually operated below 30 dBm input power [4]. This is because that the large RF input power induces significant voltage and

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current swings on a Schottky diode, which causes breakdown in the metal-semiconductor junction and permanently damages diode. To achieve a high-power RF rectifier by using a low power capability diode, a power divider is adopted to split RF input power to several diode circuits to prevent diode breakdown. Therefore, realizing a full-wave RF-to-DC bridge rectifier with a single-ended-to-balanced power dividing network to achieve high-power and high-efficiency characteristics is the major challenge of efficient wireless charging system.

Two bridge rectifiers are realized by using the presented Series Dividing Transformer (SDT) and Parallel Dividing Transformer (PDT), and the corresponding layouts are depicted in Fig. 1. In Fig. 2, results show the simulated and measured reflection coefficients $|S_{11}|$ of the half-wave, SDT and PDT rectifiers versus the input power from 0 dBm to 45 dBm at 920 MHz. Results show that all rectifiers are well-matched ($|S_{11}|<$ -14dB) at their corresponding high P_{in} operation, i.e. $P_{in} \cong$ 30 dBm for the half-wave rectifier and $P_{in} \cong$ 36 dBm for the SDT and PDT rectifiers.

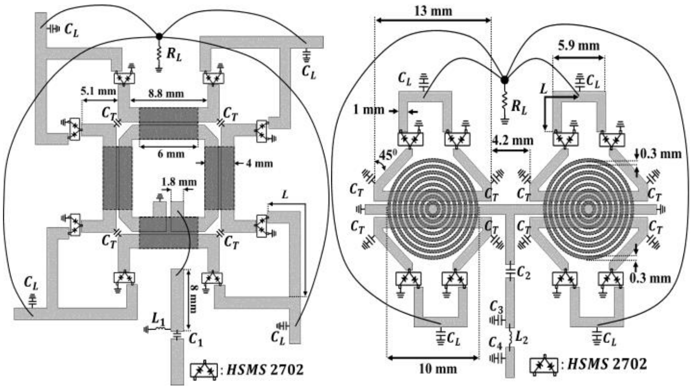

Fig. 1 Layout of the proposed rectifier. (a) SDT rectifier (=1 pF, =22 nH, =9 pF, = 1 uF, = 10 Ω, and =15.5 mm), (b) PDT rectifier. (=6.8 pF, =7 pF, =3.3 nH, =1 pF, =3.3 pF, = 1 uF, = 10 Ω, and =7 mm)

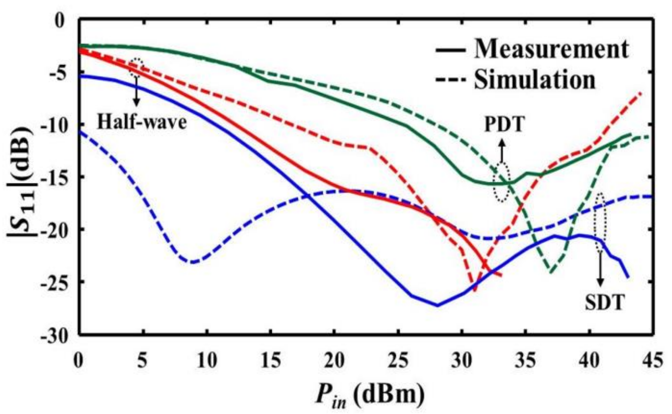

Fig. 2 Measured and simulated of SDT and PDT rectifiers versus .

Fig.3 depicts the simulated and measured η_{eff} of the proposed SDT and PDT rectifiers. The conventional half-wave rectifier is also implemented and measured for comparison [5]. A good agreement between the measurement and simulation is observed. Note that the measured η_{eff} of the half-wave rectifier using a single diode in parallel configuration declines drastically at P_{in} = 30 dBm, which is because the voltage at the shunt-connected diode of the half-wave rectifier exceeds its off-state breakdown voltage. This behavior indicates that the input driving power of the half-wave rectifier is strictly limited. Therefore, the high-power and high-efficiency characteristics of the proposed SDT and PDT rectifiers are validated by comparing with the conventional half-wave rectifier. Moreover, the maximum measured η_{eff} of PDT is 78 % at P_{in} = 43 dBm and that of SDT is 62 % at P_{in} = 41 dBm.

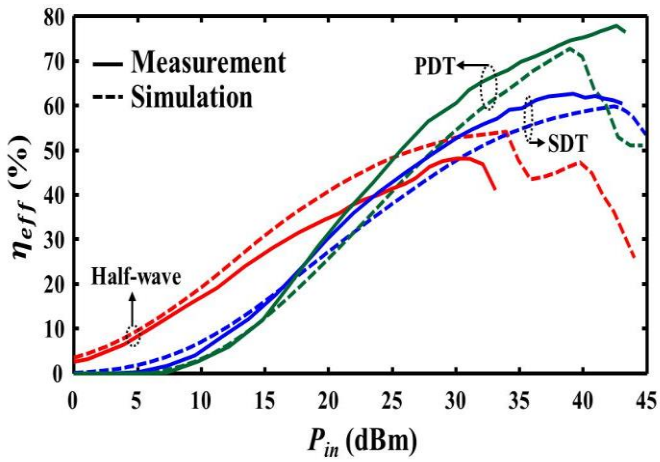

Fig. 3 Measured and simulated η_{eff} of SDT and PDT rectifiers versus P_{in} .

To demonstrate the usefulness of SDT and PDT rectifiers in the application of wirelessly powered device, the experimental setup of a HTC wildfire smartphone being wirelessly charged via the metamaterial cavity and the proposed rectifiers is established, as shown in Fig. 4.

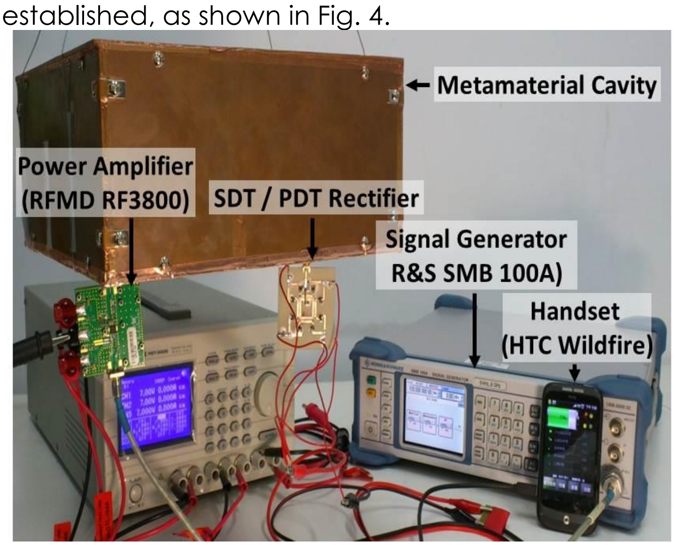

Fig.4 Measurement setup of wireless charging system of mobile handset.

The signal generator drives a hybrid GaAs HBT

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power amplifier in the frequency of 920 MHz, and the power amplifier output power 37 dBm is fed into the monopole antenna inside the metamaterial cavity and is electromagnetically coupled to the identical receiving monopole. The proposed SDT and PDT rectifiers are connected separately to the received port of metamaterial cavity to convert the RF to DC power for handset charging via a micro-USB connector. For battery capacity increasing from 5% to 80%, the charging time of mobile handset using SDT rectifier is 221 minutes, but it takes only 218 minutes for the case using PDT rectifier. Therefore, the PDT rectifier is more efficient than the SDT rectifier for the wireless charging system at watt-level RF input power.

Finally, the high-power and high-efficiency RF rectifiers using two types of transformer-based power dividing networks, SDT and PDT, have been demonstrated. To solve the low breakdown voltage problem of the Schottky diodes in the zero-bias and full-wave bridge rectifiers, the 1-to-4 SDT and PDT for impedance matching and power dividing are employed. The implemented SDT and PDT rectifiers achieve 62 % and 76 % efficiency at 920 MHz and 41 dBm input power. The wirelessly powered mobile handset using the metamaterial cavity and the proposed rectifiers is demonstrated. The presented series and parallel power dividing techniques are attractive solutions for other wireless power applications requiring high-power and high-efficiency RF rectifier, for example, the wireless energy transformations of electric vehicle and solar power satellite.

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Activities

Establishment of Double Degree Program between Graduate Institute of Communication Engineering (GICE), National Taiwan University (NTU) and Institute National Polytechnique de Toulouse - Ecole Nationale Superieure d' Electrotechnique, d' Electronique, d' Informatique et d' Hydraulique de Toulouse (ENSEEIHT), France.

To attract foreign students, to enhance the international co-operation and to broaden domestic students' worldview, with the assistant from French Association in Taiwan and the "N+i" Alliance, NTU-GICE has successfully signed the cooperation Agreement with the prestigious French school in telecommunication (Institut National Polytechnique de toulouse - Ecole Nationale Superieure d'Electrotechnique, d'Electronique, d'Informatique et d'Hydraulique de Toulouse, called INPT-ENSEEIHT) for the first Double Master's degree program. NTU-GICE expects through this program, second-year master students will take course and conduct research in the foreign institute. The double degree students will be awarded degrees by both schools. Through this program, GICE hopes to strengthen our curriculum with bilateral academic and cultural interactions.

The initiative is started by Professor Tzong-Lin Wu, Chairman of NTU-GICE in February 2014. Staff members of NTU-GICE Office and Professor Hung-Yu Wei, who leads the negotiation with the French partner went through several rounds of discussions on overall curriculum, course credits requirement, tuition fees, thesis writing, and oral defense. This event, therefore, has successfully laid the foundation for a long-term and friendly co-operation future between the two institutes.

ENSEEIHT is one of 7-branches of INP-Toulouse (National Polytechnic Institute of Toulouse) which is a prestigious institute in engineering fields. The double degree program covers the research area of electromagnetics, radio, communication, networking and signal

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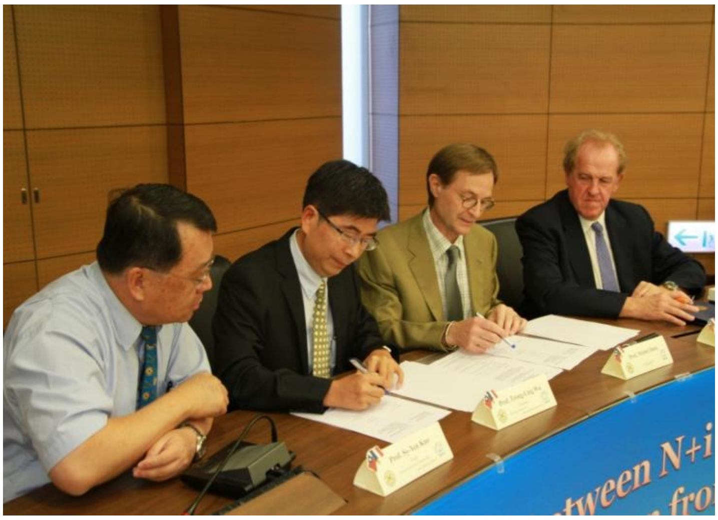
processing. Currently, ENSEEIHT has also signed the double degree agreement with Georgia Tech (US), Imperial College in London (UK). Over the past few years, there are several ENSEEIHT students visited NTU-GICE for summer research internship and performed well. The graduate program in ENSEEIHT covers 5 majors, including: electrical engineering and automation technology, computer science and applied mathematics, hydraulics and fluid mechanics, telecommunications and network technology. It is expected that through the connection, students can effectively learn French, strengthen academic expertise based on the abundant of academic resources.



From left to right, Professor Sy-Yen Kuo, Dean of EECS, Professor Tzong-lin Wu, Chairman of NTU- GICE, Professor Michel Doisy, National Polytechnic Institute of Toulouse, Professor Pierre Dauchez, Chief Executive of the N+i Alliance.

On October 21, 2014, NTU-GICE and INPT-ENSEEIHT has officially signed the Cooperation Agreement for the Double Master's degree program to launch a new page of co-operation. The signing ceremony is held in Barry Lam Hall. There are totally 11 VIP guests including: Professor Pierre Dauchez, Chief Executive of the N+i Alliance, Professor Michel Doisy from ENSEEIHT, Professor Said Zouhdi, Head of International Affairs of University of Paris XI, Professor Grondel Sebastian of University of Valenciemens, Sophie Gerbais de Lafond, International Affair of School of Advanced Electronics and Electrical Engineering Technology in Paris, Professor Sylvie Ducky from National School of Advanced Chemistry in Clermont and representative of French Office in Taiwan, participated the ceremony. The ceremony is host by Professor Si-Yan Guo, Dean of the College of Electrical Engineering and Computer Science, Professor Tzong-Lin Wu, Chairman of NTU-GICE, who officially signed the Cooperation Agreement. Many guests have witnessed this ceremony. After the ceremony, the participants continued discussions to further enhance the understanding and explore other collaboration opportunities.

Group Photo

The 3rd seasonal seminar of Taiwan Electromagnetic Industry-Academia Consortium

(TEIAC) in 2014 was held in National Taiwan University on October 2, 2014 with the subject titled by "Imagination of Communication Technologies Beyond 4G and its Technology Composition". The subject was driven by the launch of 4G mobile communications and the technology society eagers to discover the technology trend in the next generation (5G). In particular, the government has initiated several key research projects to explore the technology trend and develop key technology, where five major organizations in Taiwan have conducted attractive researches including National Taiwan University (NTU), Yuan Ze University (YZU), Industrial Technology Research Institute (ITRI), Chung-Shan Institute of Science and Technology (CSIST), and Institute for Information Industry (III). In order to provide the progress and gather the industrial versions on 5G, these five organizations were invited to present their research scopes and their progresses. In particular, NTU and YZU have focused on the technologies for the applications in the user equipment (UE) and network systems, respectively. Also ITRI, CSIST and III summarize their research scopes on the UE architecture, the RF technologies for base station system, and tentative researches of 5G on the Ku bands. An international company, known as Rohde & Schwarz (R&S), was

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also invited to present their version and observation on the international progress. The speaker, Mr. Walter Weisse, has presented the R&S capability in supporting 5G technology development, and also the recent R&S activities in forming consortiums to work with domestic partners. This seminar has attracted more than 120 attendees with most of them from the industries and academic universities. Encouraging comments have been received from the attendees to conclude the success of the seminar.

NTU High-Speed RF and mm-Wave Technology Center opening ceremony

"NTU High Speed RF and mm-Wave Technology Center in NTU" held its opening ceremony and the B4G equipment donation ceremony of Keysight technology in October 22nd. In this ceremony, the vice president of Ministry of Science and Technology, Chung-Liang Chien, the president of NTU, Pan-Chyr Yang, and the vice president of NTU, Liang-Gee Chen and the senior vice president of Keysight Technology, Guy Séné were invited.

High Speed RF and mm-Wave Technology Center is established under the contract of Industrial Fundamental Technology Project, in purpose of breaking through the bottleneck of 5G communication, from key technology to portfolio. Meanwhile, the Director of NTU GICE, Prof Tzong-Lin Wu will be the supervisor of this center, leading the team to cooperate with 5 world-class industrial participant, including Quanta computer, Microelectronics Technology Inc., Realtek, TSMC and Keysight.

In the B4G equipment donation ceremony of Keysight, the president of NTU, Pan-Chyr Yang and the senior vice president of Keysight Technology, Guy Séné forward exchange contract, in which Keysight Technology should provide equipment that value above 12 million NTD, and establish "B4G MIMO RF Measurement Lab" for the Industrial Fundamental Technology Project.

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Director Tzong-Lin Wu mentioned that five well-known industries has joined this project, contributing their resources in different aspects, including base station specification, chip specification, chip packaging process and system specification. Thanks to their efforts, this project has brought about multiple technology transfers and industry-university cooperation in less than one year.

Corner of Student News

by Mazen Almalki

Mazen Almalki comes from Saudi Arabia and he is studying Master program at NTU GICE.

This is my first semester and also the first time I am coming to Taiwan as student. I would say that it is totally different here compared to other countries. I am really enjoying and spending a great time here. The most unforgettable thing in Taiwan is the people. They are so kind, lovely and helpful. Throughout my life, there have been several events and people that influenced significantly who I am today. Among those things, Coming to Taiwan has become the most important influence in my life. I learned to adjust myself to new culture that is completely different from my background. I have adapted this new culture in some extent Acquiring new language ability is considered to be cognitive complexity, and this development affected me. I had a hard time getting used to a new life in a different country especially the communications part .Most of my friends speak Chinese, Also, all my classes I was taking at that time were pretty hard, I couldn't even understand what my teachers were talking about in classes. But all the people here (the professors and students) always trying to help me as can as possible .Later I found out the easiest way to improve my language skill is talking. First, I had to learn how to communicate with people in Chinese and went through hard time during the process. By now, I have acquired Chinese ability that allows me not to have trouble handling things in the daily life. Although there were still lots of things I didn't know, but it I think once I have the language foundation, everything would become easier.

Taiwan has a lot to be proud of – like the landscape, cultures, hot springs and National Anthem. The more I think about it the more I come to have great respect for Taiwan. Taiwan is fair, kind, safe and offers support to every person. It is affordable and has great education programs. Finally, I would say that Taiwan how beautiful you are!

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