
NTU GICE
Newsletter
Graduate Institute of Communication Engineering, National Taiwan University

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In this issue

Technology Developed in GICE

Device-to-Device Communication with Simultaneous Transmission

from Communication and Signal Processing Group

Device-to-Device (D2D) communication allows direct communication of a device to another device without traversing a base station. It takes advantage of the physical proximity of communication devices to achieve high bit rate, low delay, low power consumption, and dense frequency reuse. In the current cellular system, the D2D operation lets D2D users and cellular users use orthogonal radio resources (see Fig. 1) [1]. There is no interference between D2D and cellular links, but the efficiency of frequency reuse is low.

This research proposes a scheme that allows a D2D user to simultaneously transmit its D2D and cellular signals, in the uplink portion of the time, to improve the performance (see Fig. 2). The idea is to superpose the D2D signal and cellular uplink signal of a user, and use either a precoding method, such as dirty paper coding (DPC) [2][3], at the D2D transmitter, or successive interference cancellation (SIC) at the D2D receiver, to cancel the cellular uplink signal (which is usually much stronger due to the longer distance from the device to the base station) at the D2D receiver for a clean demodulation and decoding of the D2D signal (which is usually much weaker due to the shorter distance between D2D devices). As a result, a small amount of the uplink power can be used to exchange for a large D2D rate, while the interference of the D2D signal to the uplink signal is almost negligible.

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GICE Honors

Prof. Hsi-Tseng Chou
「The 5th National Innovation Industrial Award 」

Prof. Tian-Wei Huang
「2017 IEEE Fellow」

Message from the Director

Tzong-Lin Wu

Professor & GICE Director

A fresh new year is once again upon us, we are thankful for the supports of the past year. 2017 is a brand new year to start afresh, to start strong, and to complete everything we want to do this year.
We wish our efforts to blossom as those flowers on this beautiful February.

This is the first quarterly issue of NTU GICE Newsletters in 2017; we invited Professor Hsuan-Jung Su and Professor Huei Wang to share their recent progress, wish you enjoy the reading. In addition to reports on GICE technology and activities, we are happy to share Prof. Tian-wei Haung crowned 2017 IEEE Fellow and Prof. Hsi-Tseng Chou won National Industrial Innovation Award in the area of smart technology.
GICE team again demonstrates outstanding research capability!

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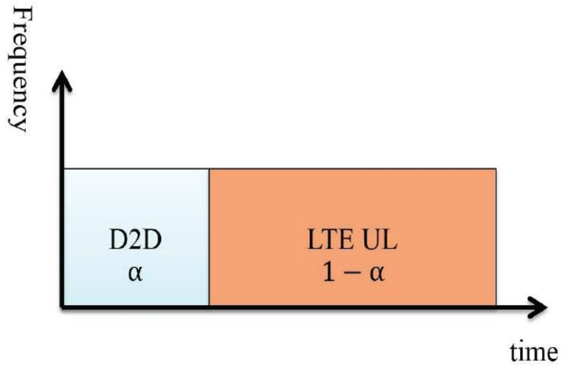

Figure 1: Orthogonal radio resource division in the cellular uplink spectrum where D2D devices are allocated α portion a of the time.

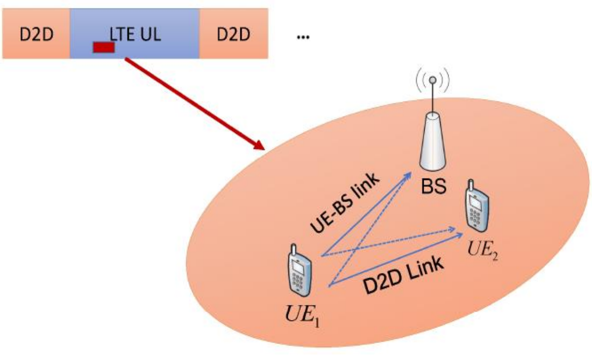

Figure 2: Simultaneous cellular uplink and D2D transmission.

For the cellular uplink portion of the time, to maximize the total transmission rate (including cellular uplink and D2D rates) from a device subject to the total power constraint and the constraint that a certain amount of the cellular uplink rate is destined to other cells and cannot be offloaded to D2D communication, the following optimization problem is formulated

$$\begin{aligned}\max_{P_{UL},P_{D2D}} \quad & \log\left(1+\frac{P_{UL}G_{UE,BS}}{N+I_{D2D}}\right) \\ & +\log\left(1+\frac{P_{D2D}G_{D_{TX},D_{RX}}}{N}\right) \\ \text{subject to} \quad & P_{UL}+P_{D2D}\le P_{total}, \\ & P_{UL}\ge 0, \quad P_{D2D}\ge 0, \\ & \log\left(1+\frac{P_{UL}G_{UE,BS}}{N+I_{D2D}}\right) \\ & \ge p\log\left(1+\frac{P_{total}G_{UE,BS}}{N}\right),\end{aligned}$$

where P_{total} is the maximum allowed transmission power; P_{UL} and P_{D2D} are the power allocated to the cellular uplink and D2D signals, respectively; $G_{UE,BS}$ and $G_{DTX,DRX}$ are the channel gains between the transmitter and the base station, and between the transmitter and the D2D receiver, respectively; I_{D2D} is the interference caused by the D2D signal to the cellular uplink; and N is the additive noise seen at the receivers (which is assumed the same at the base station and the D2D receiver for simplicity); and p is a factor denoting the portion of the uplink rate that cannot be offloaded to D2D communication. When the devices and the base station are all equipped with single antenna, this problem can be easily solved. If any of them has multiple antennae, more complicated solving techniques, such as iterative waterfilling [4][5], can be modified to solve the problem.

Using the parameters in Table 1 and assuming that the base station has four antennae, the devices have two antennae, and perfect DPC is implemented at the transmitter to completely remove the interference of the uplink signal at the D2D receiver, the performance of the proposed method is

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evaluated. It can be seen from Fig. 3 that, depending on the time ratio a in the conventional D2D scheme specified in Fig. 1, the proposed scheme can improve the total D2D rate by up to 30 times.

Simulation Parameters	
Network Scenario	3 Cell Cell Radius = 500m
Path Loss Model	Winner + B1
Bandwidth	10 MHz
Carrier Frequency	2 GHz
Traffic Model	Full Buffer Traffic
Shadow Fading Standard Deviation	7dB
Fast Fading Model	ITU-R IMT UMi
Number of UEs for D2D Discovery	150 per Cell
Number of UEs with UL Traffic	25 per Cell
UE Distribution	Uniform
UE Power Constraint	10 dBm
Thermal Noise	-174 dBm / Hz
Minimum RSRP for D2D Communication	-112 dBm
Minimum UL Rate Ratio p	0.8 unless otherwise specified

Table 1: Simulation parameters.

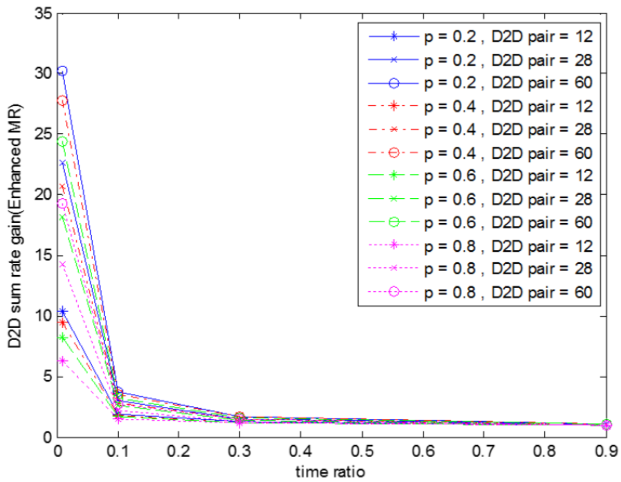

Figure 3: The ratio of the D2D rate of the proposed scheme over the D2D rate of the conventional scheme specified in Fig. 1, where the time ratio is a in Fig. 1.

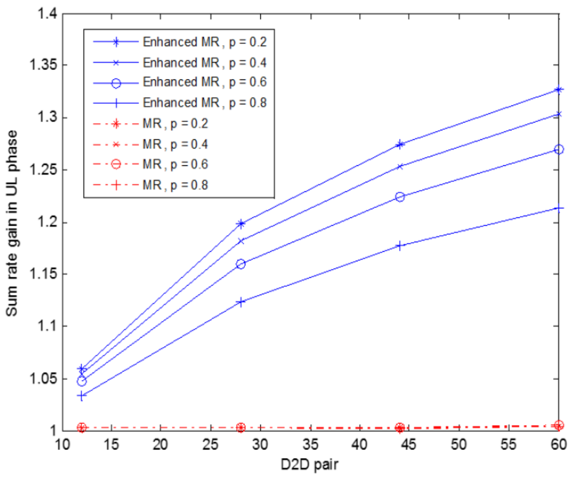

Figure 4: The ratio of the achieved sum rate (in the uplink time slots) over the uplink rate of the conventional scheme.

In the uplink portion of the time, the proposed simultaneous transmission can increase the sum rate (of uplink and D2D) to up to 1.32 times the original uplink rate of the conventional scheme, as shown in Fig. 4. This increase comes mainly from the simultaneously transmitted D2D signal which requires very little power. In Fig. 5, it is shown that the loss of the cellular uplink rate due to the power allocated to the D2D transmission is at most 3.5%.

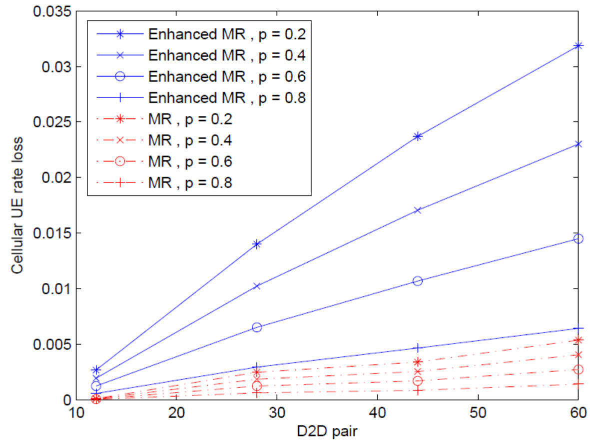

Figure 5: Normalized uplink rate loss of the proposed scheme compared to the conventional scheme without simultaneous D2D transmission.

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For more information please contact:
Professor: Hsuan-Jung Su
Email: hjs@ntu.edu.tw

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Technology (Continued from page 3)

Multi-channel millimeter-wave transceiver in CMOS for automotive radar applications

from Electromagnetics Group

Introduction

Automotive radar systems have been developed and attracted by vehicle industry for a while. The frequency band of 76-77 GHz is available in most of countries, and may be extended from 77 to 81 GHz for short range radar applications in the future [1].

Although III-V-based and SiGe-based automotive radar transceivers have been well developed [2]-[3], in order to cut costs of radar modules with the same detectability and safety, advanced CMOS technology is a new choice because of the low cost and high level integration property. To implement a radar transceiver for advanced automotive applications such as angular identification and resolve phase noise problem in CMOS-based frequency source, we adopted the injection-lock frequency sextupler (ILFS) with medium power amplifier (MPA) [4] cascading a LO split network as the LO-chain, and integrated it with two transmitters and six receivers (2T6R) to implement a multi-channel TRX using 65-nm CMOS technology, as shown in Fig. 1 [5].

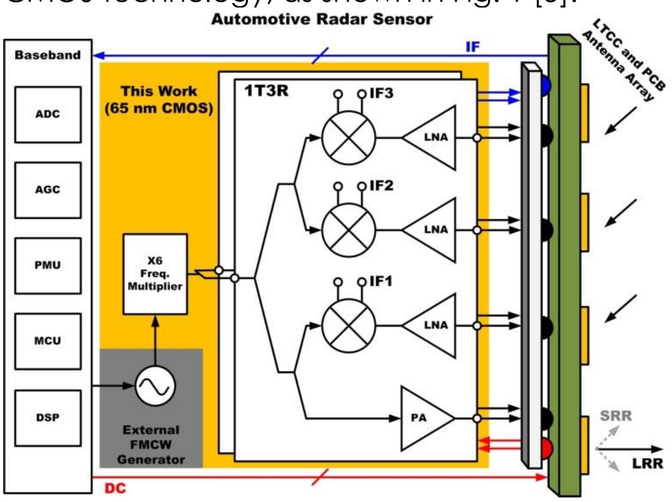

Fig. 1. Proposed complete multi-channel transceiver for automotive radar application.

System Plan and Implementation

The whole system specifications are calculated based on radar design principle [6] which estimates the relationship between transmitted power P_T and received power P_R. Besides, we also need to specify the lowest detectable power level of RX by signal-to-noise ratio, noise figure of an overall RX (NF_{tot}), and bandwidth (BW) criteria. For a typical application of automotive radar [7], we can plot a figure describing the relationship between these specifications, as shown in Fig. 2. In our design, we think 13-dBm output power is reasonable in this frequency using 65-nm CMOS. To achieve above 100-meters detectable distance, $NF_{tot,max}$ should be designed below 28 dB. Thus we specify the RX should provide at least 30-dB gain and 6-dB NF of the LNA.

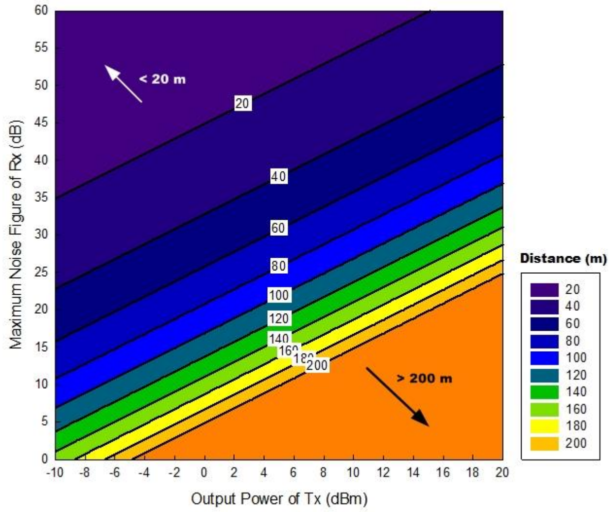

Fig. 2. The relationship between transmitted power and noise figure of the transceiver under maximum detectable distance R_{max}.

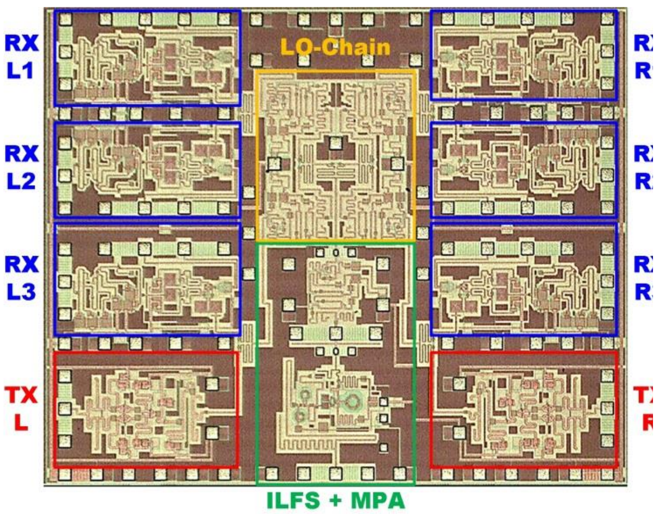

Fig. 3. The chip photo of the 2T6R transceiver with injection–lock frequency sextupler using 65-nm CMOS GP for automotive radar application. The chip size is 3.63 × 2.91 mm².

Based on these criteria and linked budget estimation, we can design each circuit block

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and integrate that as a multi-channel TRX. Fig. 3 shows the overall 2T6R TRX chip photo with chip size 3.63 × 2.91 mm^2. The measured output power of the two TXs achieve average 13 dBm under 3-dBm input power drive in CW testing, as shown in Fig. 4(a). Fig. 4(b) presents the measured phase noise -95 dBc/Hz at 10 kHz offset using an input source with -110-dBc/Hz phase noise at 10-kHz offset frequency. We also do FMCW testing using an input source with 80-MHz chirp BW in 2-ms period, and the measured output spectrum of the TX shown in Fig. 4(c) obtains 480-MHz chirp BW. The measured and simulated conversion gains of six RX channels versus IF frequency is shown in Fig. 5(a) with fixing LO frequency at 12.75 GHz and achieve above 31 dB with below 1.2-dB variation between each channel for IF below 10 MHz. Fig. 5(b) presents around 8.8 dB measured single-sideband (SSB) NF of six RXs at 78 GHz, and the NF of six RXs are consistent.

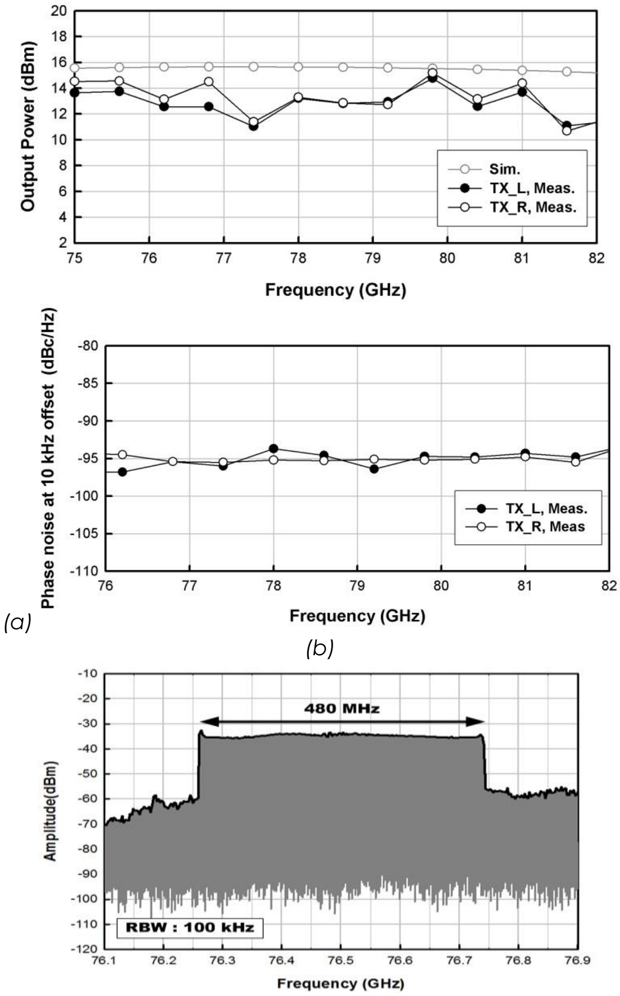

Fig. 4. (a) The simulated and measured output power of two transmitters and (b) the phase noise at 10 kHz offset frequency using SG as input signal with -110 dBc/Hz-phase noise at 10 kHz offset. (c) Frequency spectrum with FMCW input signal.

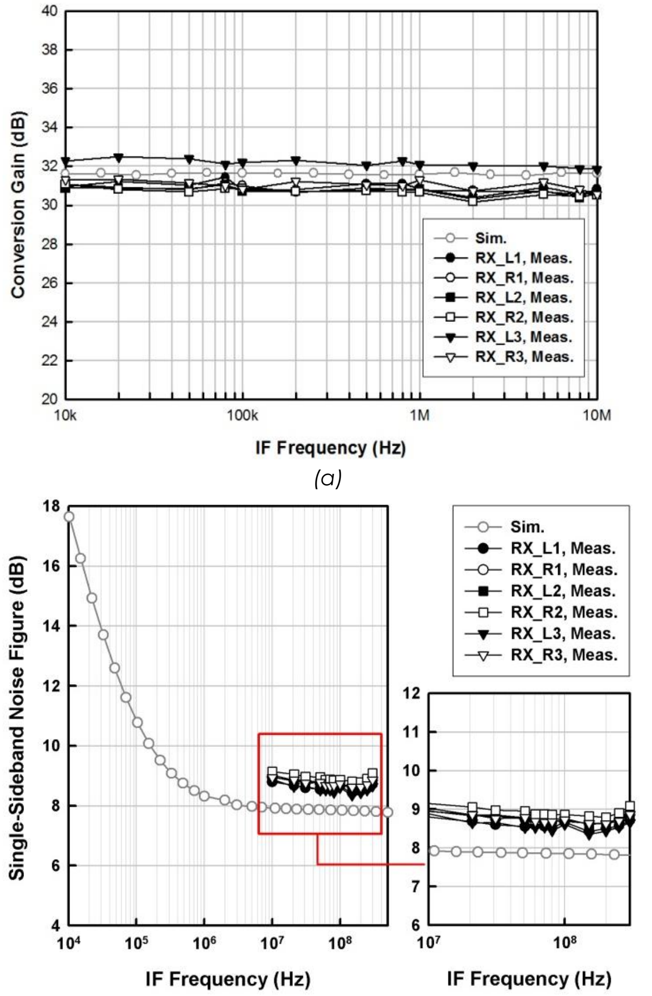

Fig. 5. The simulated and measured (a) conversion gains versus IF frequency and (b) The simulated and measured single-sideband noise figure of the RXs. The LO is fixed at 13 GHz corresponding 78 GHz at output of the LO chain.

Conclusions

In this work, we proposed and designed a W-band multi-channel TRX using 65-nm CMOS for automotive radar applications. Two TXs, six RXs are integrated with ILFS and the 1-to-8 LO-chain on the same die. The overall chip size is 3.63 × 2.91 mm^2 with 1.43-W dc power. Compared with published Si-based W-band automotive radar TRXs, the experimental results show that the proposed TRX achieves compatible performances and the potential of CMOS technology in advanced automotive radar applications.

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For more information please contact:
Professor: Huei Wang
Email: hueiwang@ntu.edu.tw

Activities

- EMC Joint Workshop Taipei 2016

EMC Joint Workshop Taipei 2016, (EMCJ 2016) was held on June. 2nd and 3rd at Barry Lam Hall in National Taiwan University at Taipei, Taiwan. This joint was supported by Taiwan Electromagnetic Industry-Academia Consortium (TEMIAC), IEEE EMC Society Taipei Chapter and IEICE Taipei Section. Both EMC group from Japan and Taiwan are invited in this joint. Also, many leading industries in Taiwan participated in this joint. It is an unprecedented grand event for EMC groups in Japan and Taiwan.

There are three parts for the technical program, including oral regular session, invited speech and poster sessions. And all the presentation is held in single conference hall this time. So participants would not miss any presentation. In the following parts, some remarkable researches will be captured from the oral presentation sections.

For the demand of high performance computing or communication electronic circuits, multilayer printed circuit board (PCB) and package, it is more difficult to maintain good signal/power integrity (SI/PI) and electromagnetic interference (EMI)/electromagnetic compatibility performance than before. So how to enhance the SI & PI and degrade EMI are the main issues nowadays. Chi-Kai Shen, from NTU EMC group, proposed a design method of capacitance to enhance the bandwidth of Electromagnetic Bandgap structure (EBG), which is a periodic structure usually used to enhance power integrity. Also, Doc. Sho Muroga from Toyota College, proposed a meltblown, non-woven fabric type suppressor for non-magnetic noise shielding. This fabric can enhance the antenna sensitivity and is compact for wearable devices.
In recent years, to break the coming physical limit of Moore's law, three-dimensional integrated circuit (3D IC) was regarded as the most important part for IC development. However, 3D structure with Through Silicon Via

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Activities

(TSV) is complicated and the SI/PI/EMI issues are still exist. Yi-An Hsu from NTU EMC group proposed a prediction method by analyze the capacitance in depletion region. This method offers consistent results with simulation from commercial software and is more efficiency. Also, Chi-Hsuan Cheng from NTU EMC group, proposed a TSV-based common-mode filter for suppressing noise in 3D-IC. His design can solve the EMI and RFI problem and finally get 106% fractional bandwidth for the filter.

Two Invited speeches were given by speaker from Taiwan and Japan, respectively.
First, Doc. Tzvy-Sheng Horng form National Sun Yat-sen University, give a talk about the modeling of vertical interconnect in PCB. By using the method of image charges between signal and ground lines, a theory can be derived and verified. Also, the measurement of single-ended and differential TSV by double sided probing system are shown by the speaker.
In second day, Doc. Yu-ichi Hayashi from Tohoku Gakuin University, introduced a special issue about display stealing security in tablets PC to participants. The speaker estimated the EM leakage from conventional display and constructed a block diagram and measurement system to capture the leakage. After all, the speakers showed that although the EM leakage in mobile devices is small and the capturing of leakage should be done in short time because the movement of people in public space is fast, the security of information should still be protected.

Poster section was also included in this workshop. All the poster presenter should give a briefly oral presentation about 3 minutes before presenting their poster in poster area. So the participants can get roughly idea of all the research and find the interested ones more efficiently.

Technical visit for the EMC lab was held after the ending of technical section. The participants from Japan were invited to have this tour. There are three parts in this tour, including Packaging lab, EM Design for Advanced Packaging Lab and Anechoic chamber. All the labs were introduced by EMC group members from NTU.

Besides general technical program, EMCJ also offer social program for participants, including the Campus visit before the day the joint started and the Banquet. All the participants have a nice time to share the culture, life time and experience on research through these chances. We hope that there will be more and more chance for the EMC groups from Japan and Taiwan to carry on academic exchange in the future.

Delegates visited EMC labs in NTU.

Gift Exchange.

Group photo

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- EMI Effect and Design Challenge on MIMO Wireless Communications and Advanced Automotive Electronics

To enhance the communications and cooperation between industrial and academic sections on Electromagnetic Compatibility issues related to wireless communications performance, Taiwan Electromagnetic Industry-Academia Consortium held the First 2016 semi-yearly workshop in the Sixth International Conference Hall of Feng Chia University on June 23. The theme of the quarterly workshop is "EMI Effect and Design Challenge on MIMO Wireless Communications and Advanced Automotive Electronics ", and it was organized by Taiwan Electromagnetic Industry-Academia Consortium and Integrated Circuits Electromagnetic Compatibility Research Center and FCU Department of Communication Engineering. To wide spread the participating technical communities, the workshop also invited IEEE EMC Taipei section, Taiwan Institute of Electrical and Electronic Engineering, Microwave Organization of Taiwan, Electronics Testing Center . The workshop attracts more than 100 people to participate the lectures and panel discussion sections. The participators come from various aspects of the industries including TSMC, ASUS, Hon Hai (Foxconn), HiMax, Inventec Appliances Corp., ATL, ASRock, USI, REALTEK, Auden, ITRI, SGS, SPIL, ICC, MTI, CIC and others. There are also enthusiastic professors and students from several universities including NCCU, CYCU, NCHU, NUU, DYU, LHU, FCU and others. The quarterly workshop was a great success with enthusiastic response from all attendance.
The programs are divided into two half-day technical lectures sections and a panel discussion. The workshop began with opening speech from Professor Tzong lin Wu, Chairman of Taipei EMC Chapter and Department of Electrical Engineering of National Taiwan University, then followed by Professor Lin from IEEE EMCS Taipei section then followed by Minister Wang from BSMI. The lectures began from Analysis of MIMO OTA Performance Degradation from Platform Noise by Mr. Han-Nien Lin from FCU and followed by continuing lectures with effect investigation from other speakers. The activities of the programs were quite wonderful and attractive, and it also arranged together with the coffee breaks in the middle of the morning and afternoon screening time to provide a joy time for discussion.

The lectures and topics of the workshop are as following:

1. **Analysis of MIMO OTA Performance Degradation from Platform Noise** — By Professor Han-Nien Lin, Feng Chia University.
2. **MIMO OTA Practical Testing Techniques** — By Frank Tsai, General Manager of TRC.
3. **Hardware System Design and EMC Technology for ADAS** — By Ikker Zheng, Engineer of ARTC.
4. **Antenna simulation for IoT(Internet of things) and IoV(Internet of Vehicle)** — By Ding-Hao Yeh, Application Engineer of ANSYS, INC., Taiwan Branch.
5. **Design of MIMO antenna for Mobile Devices** — By Professor Ding-Bing Lin, National Taipei University of Technology.
6. **Electromagnetic Interferences Occured in the Large BTS** — By Professor His-Tseng Chou, National Taiwan University.

National Taiwan University Graduate Institute of Communication Engineering

No.1, Sec.4, Roosevelt Road,
Taipei 10617, Taiwan

Phone
+886-2-3366-3075

Fax
+886-2-2368-3824

E-mail
gicenewsletter@ntu.edu.tw

Visit us at:
http://www.comm.ntu.edu.tw

Editor in Chief
Prof. Hung-Yu Wei

Editor
Chiao Yun Kang