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Technology Developed in GICE

A New Broadband Common-Mode Noise Absorption Circuit for High-Speed Differential Digital Systems

from Electromagnetics Group

Differential signaling is a popular technique in delivering high-speed digital input/output (I/O) signals, such as USB 3.0, HDMI, PCIE, etc., because it is less sensitive to the reference plane disturbance and has lower crosstalk and radiated emission 0. High-speed differential signals transmit between two electronic devices through cables and/or connectors. However, these cables or connectors will become a good radiator (or antenna) excited by the common-mode noise, which usually accompanies with the differential signals due to the inevitable asymmetry in package layout or I/O buffer design. The unintended radiation from common-mode noise will sometimes cause electromagnetic interference (EMI) or radio-frequency interference (RFI) problems for electronic devices or systems [2].

As shown in Fig. 1, inserting a common-mode filter (CMF) before connectors or cables is a typical solution to prevent the common-mode noise emission from exciting the radiators (cables or connectors) and thus reduce EMI or RFI. CMF behaves as an all-pass response from dc to very high frequency for differential mode in order to maintain good signal integrity (SI), and a band stop (or low-pass) response for common mode to suppress the noise. Several types of CMF have been proposed. There are common-mode choke using ferrite materials, coupled resonators approach based on pattern ground structures, and the meta-material concept using periodic structures. The idea to suppress common-mode noise for these CMFs is reflection. CMFs become very high impedance (open circuit) in series or very low impedance (short circuit) in shunt and thus the common-mode noise is reflected due to the impedance mismatch. However, the reflected common-mode noise still exists inside the device or systems, and has high possibility to cause SI or EMI/RFI problems and degrade the system performance.

(Continued on page 2)

GICE Honors

Prof. Ping-Cheng Yeh
「NTU 104 Award for Outstanding Teacher in Social Services」

Prof. Lin-Shan Lee
「2015 Presidential Science Prize of Taiwan」

Prof. Ming-Syan Chen
「Y.Z. Hsu Scientific Award-The Thirteenth Scientific Chair Professor」

Message from the Director

Tzong-Lin Wu

Professor & GICE Director

In this issue, we still publish two outstanding research outcomes to all friends who are deeply concerned about NTU GICE matters.
Hoping you can gain benefits from these excellent research results.

We have good news to share that Professor Lin-Shan Lee received Presidential Science Prize of Taiwan in 2015 which is a great honor in Taiwan for the academic achievement.
This issue highlights the activity of Asia-Pacific International EMC Symposium and Exhibition (APEMC 2015) which was successfully held on May 25-29 in Taiwan.

Please enjoy the last periodical in 2015, we wish you have an instructive read.

Technology

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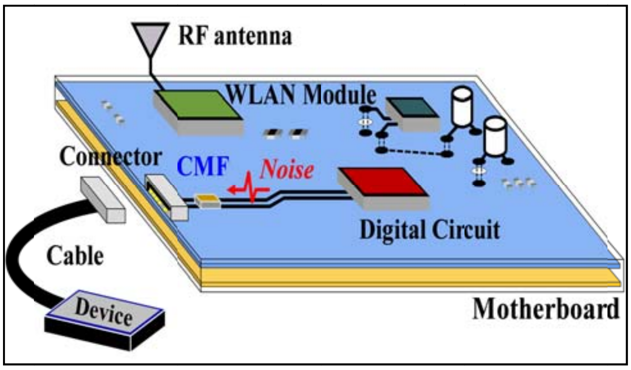

Fig.1 Position of the conventional common-mode filter (CMF) in high-speed digital systems.

Based on the idea of energy absorption for the common-mode noise, this article presents a novel absorptive CMF (A-CMF) with both horizontal and vertical symmetry, as shown in Fig. 2. Due to the circuit symmetry, the A-CMF behaves like a transmission line with series *L* and shunt *C* elements for differential mode. On the other hand, the A-CMF looks like a reflectionless low-pass filter for common mode. In other words, common-mode energy is absorbed by the A-CMF for the frequencies above the transmission zero (f_0) of the inverse Chebyshev low-pass filter. The absorbed energy is dissipated in the resistive elements of the proposed A-CMF.
A design sample is implemented by GIPD process as the photograph shown in Fig. 3. The differential input ports (port 1 and 3) and output ports (port 2 and 4) are at left and right sides of the circuits, respectively. The square spiral is used to realize the inductors in this A-CMF. The layout occupies only 1 mm^2, excluding probing pads and the surrounding ground rings.

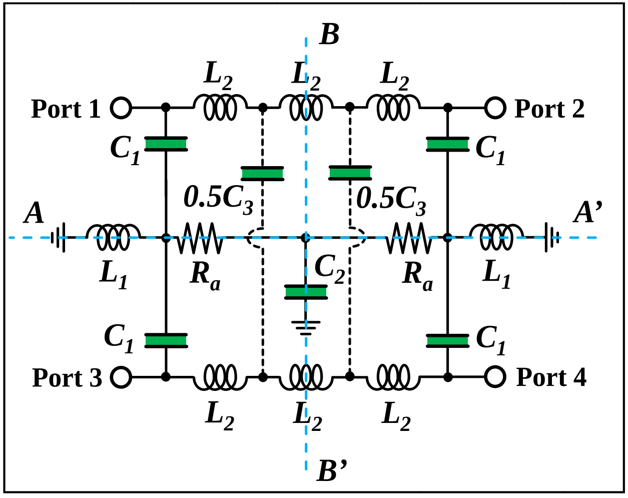

Fig. 2. Proposed absorptive common-mode filter (A-CMF). The horizontal symmetrical line AA' and the vertical symmetrical line BB'.

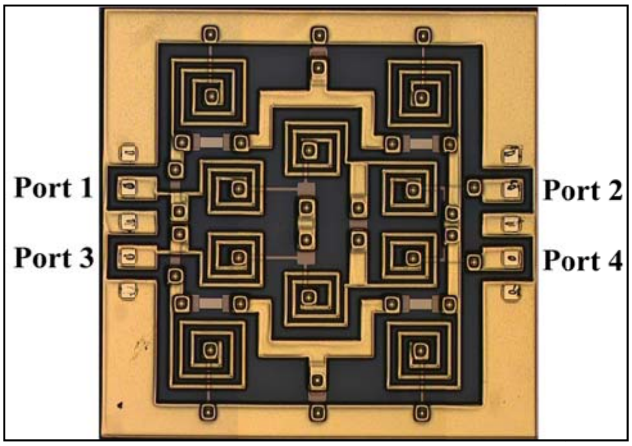

Fig. 3. Photograph of the fabricated A-CMF. The layout occupies only 1 mm^2, excluding 100-um GSGSG probing pads and the surrounding ground plane.

Fig. 4(a) shows the reflection and transmission coefficient of common mode. The dash line represents the measured results, and the solid line means the full-wave simulated results with ANSYS HFSS 15, where an air box (1.5 mm side length) with radiation boundary is outside the simulated structure. Good agreement is found between them. It is obvious that $|S_{cc21}|$ has a low-pass response with a transmission zero at around 5.5 GHz.
Fig. 4(b) shows the frequency response of the power loss ratio (δ_L) for common mode. The maximum power loss ratio is about 90% at 5.5 GHz and gradually drops when the frequency goes higher. However, it still has over 80% of common-mode power absorption in wide frequency range from 4 GHz to 14 GHz. The EMI/RFI problems would be significantly reduced by this A-CMF through absorbing 80% of the common-mode noise.

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Technology *(Continued from page 2)*

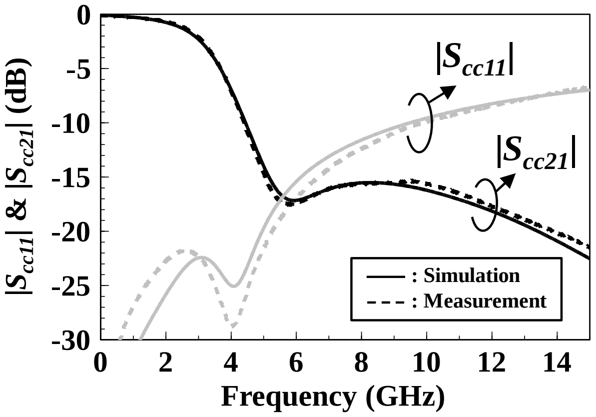

Fig. 4.**(a)**

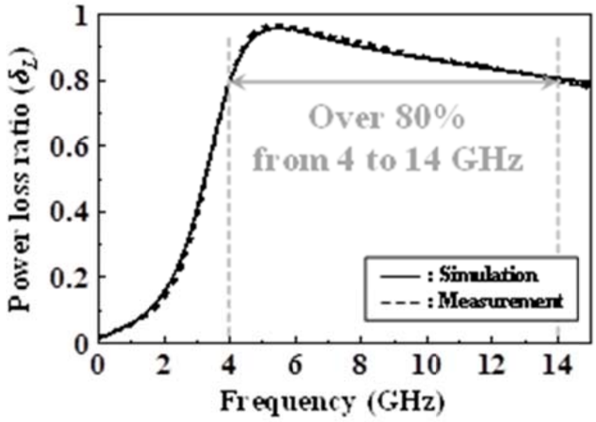

Fig. 4.**(b)**

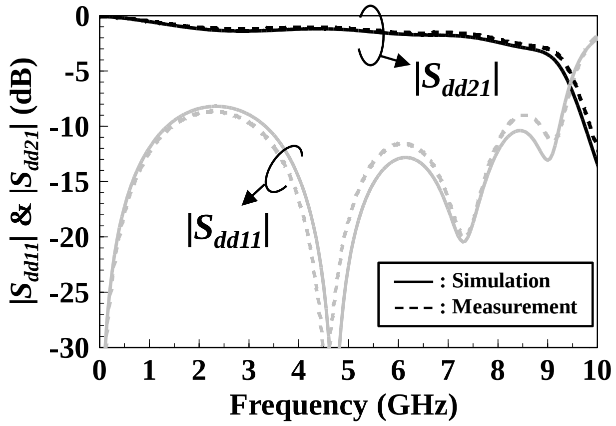

Fig. 4.**(c)**

Fig. 4. (a) Common-mode responses (|S_{cc11}| and |S_{cc21}|), (b) common-mode power loss ratio (δ_L), and (c) differential-mode responses (|S_{dd11}| and |S_{dd21}|) of the A-CMF.

The absorptive energy is transferred to heat by the resistor R_a. It is worth noting that δ_L is seldom over 10% based on conventional CMF designs [3]-[5] because most of the common-mode power is reflected. The reflected common-mode noise has high possibility to cause SI and EMI/RFI problems in real circuit systems.

The differential-mode responses (|S_{dd11}| and |S_{dd21}|) by measurement and full-wave simulation are presented in Fig. 4(c). Good agreement between them can also be seen. The ripples of |S_{dd21}| caused by impedance mismatch become unapparent both in measurement and full-wave simulation, which is due to material losses.

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Transmission Scheduling for Non-Orthogonal Multiple Access (NOMA) in Next-Generation Communication Systems

from Communication and Signal Processing Group

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Technology

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Introduction

In orthogonal multiple access (OMA), individual users are allocated orthogonal radio resource blocks (e.g. time slots and sub-channels) for communications with the base station. While OMA technology such as orthogonal frequency division multiple access (OFDMA) has been popularly used in existing communication systems, a move towards non-orthogonal multiple access (NOMA) has recently caught the limelight. NOMA allows multiple users to share the same resource block previously allocated to only one user in OMA such that simultaneous transmission of more than one layer of data for more than one user *without time, frequency and spatial layer separation* is possible. To support NOMA, the base station (BS), for example, can apply superposition coding to mix symbols intended for multiple users before transmission. After receiving the mixed symbols, each user can then perform iterative decoding based on successive interference cancellation (SIC) to remove undesired components. With perfect interference cancellation, such multi-user superposition transmission (MUST) scheme has been shown theoretically to outperform existing transmission schemes in LTE.

While NOMA can potentially achieve significant performance gain over OMA, it has raised new challenges. In particular, power allocation among superposed symbols needs to be carefully determined to ensure proper interference cancellation. Take the case of two NOMA users each with QPSK-1/2 as the modulation and coding scheme (MCS) for example. Let User 1 be a near user (with a larger channel gain) that applies SIC for decoding its own symbols and User 2 be a far user that directly decodes its own symbols by treating User-1 symbols as noise. Let α ($0 < \alpha < 1$) be the power allocation factor for User 1 such that $P_1= \alpha P$ and $P_2=(1-\alpha)P$ are the powers allocated to User 1 and User 2 respectively. As we can observe in Fig. 1, a larger value of α implies smaller allocated power and hence higher BER (bit error rate) for User 2. For User 1, however, its BER first decreases but then increases as the value of α increases (refer to the curve based on simulation). The reason is because User 1 needs to first decode and remove the symbols of User 2 before its symbols can be correctly decoded. Therefore, although a larger value of α can result in better decoding of User-1 symbols, when the power allocated to User 2 is too small, User 1 suffers from *error propagation* due to incorrect decoding of User-2 symbols. Such phenomenon is not observed in the theoretical model that does not take the impact of imperfect interference cancellation into consideration. Furthermore, it can be observed from Fig. 1 that if the BERs of the two users are required to fall below a threshold of, say, 0.002, then the values of α to use for successful multiplexing of the two users are limited to a small range between 0.06 and 0.085. Therefore, power allocation plays a key role in scheduling multiple users for resource sharing.

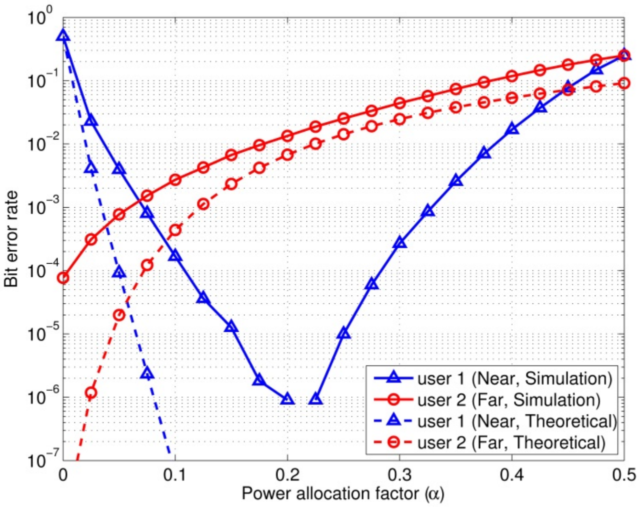

Fig. 1: Impact of power allocation on NOMA

Transmission Scheduling for NOMA

For any given set of users to serve within the coverage area, a BS that supports NOMA needs to determine how individual users are scheduled in same or different resource blocks for ensuring that the service quality of every user (e.g. minimum data rate and maximum BER) is met while maximizing the desired metric (e.g. proportional fairness metric) of the overall system. To schedule users for NOMA, we formulate a *joint optimization problem involving transmission schedule, MCS selection, and power allocation*. Specifically, we aim to determine the resource block to schedule for each user (binary variable) as well as the power allocation factor (continuous variable) and MCS index (integer variable) to use for each user in the scheduled resource block. The objective is to maximize the sum of logarithmic data rates (i.e. product of data rates) of individual users subject to the constraints that (i) each resource block can be allocated to one or multiple users, (ii) the total power to allocate to each resource block is pre-determined irrespective of the number of users scheduled therein, (iii) each user should be provided with a minimum data rate, and (iv) the BER of each user should not exceed a maximum allowable threshold. Together with the variables, objective and constraint functions, the formulated problem belongs to mixed-integer non-linear programming (MINLP).

To solve the problem, we decouple the problem into (i) a sub-problem to determine the subset of scheduled users and their MCS settings for each resource block and (ii) a sub-problem to determine the power allocation factors for the given subset of users and corresponding MCS settings. The output of the proposed power allocation algorithm is designed as an MCS map, where for the given set

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of NOMA users the sets of feasible MCS settings (and power allocation factors) that satisfy the target BER threshold under different channel conditions are obtained. Fig. 2 thus shows the map of the feasible MCS settings, where, for sake of clarity, only the MCS setting with the largest value of the *product of data rates* is plotted. It can be observed that larger performance gain can be achieved with larger difference in the channel gains of the two users. Based on the MCS map, the proposed scheduling algorithm applies the cross-entropy method to determine the optimal set of users to schedule and their MCS settings in every resource block such that the product of user data rates is maximized (for proportional fairness scheduling).

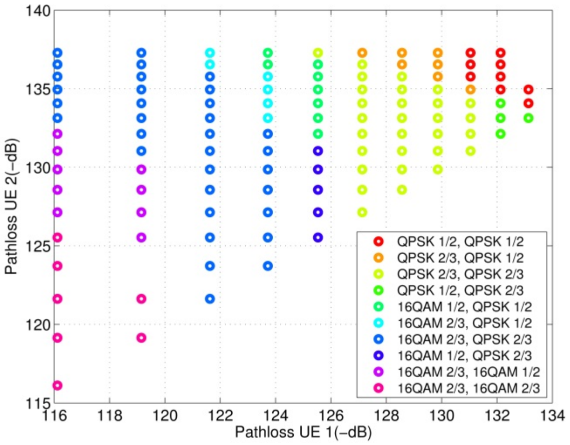

Fig. 2: MCS map for two NOMA users

Evaluation Results

To evaluate the performance of the proposed algorithms, we build a link-level NOMA simulator. The simulation scenario considered involves a macrocell of radius 1.7 kilometers with the BS located at the center and users randomly scattered within the cell. The total amount of resource blocks to schedule at once is 24, and the maximum number of users that can share a resource block is 3. The target BER threshold is 10^{-4} while the BS transmission power is 5mW/MHz and background noise is −144dBm.

Fig. 3 shows the schedule of 20 users based on the proposed algorithms. For ease of illustration, user indices are sorted by their distance to the BS. It can be observed that users with disparate channel conditions tend to be scheduled in the same resource block. Some resource blocks may schedule users with similar channel conditions to ensure the minimum data rate requirement can be met and fair resource allocation among users can be achieved. Fig. 4 further shows the performance of the proposed algorithms with and without the minimum data rate constraint (4 bps/Hz per user). For proportional fair scheduling without the per-user minimum data rate constraint, it can be observed from the bottom sub-figure that NOMA has a 100% gain over OMA. When the minimum rate is imposed, the sum rate suffers as expected (refer to the dashed line). However, the benefit is that every user always achieves at least the minimum data rate. As we observe in the bottom sub-figure, OMA fails to support more than 15 users in the cell while the proposed method can support at least 20 users with the minimum data rate constraint. The gain is consistent as the minimum rate is varied as the Y-axis of the top sub-figure shows. For a minimum rate of 6 bps/Hz, for example, NOMA can support 15 users while OMA can support only 10 users. Therefore, with proper scheduling and power allocation of users for resource sharing, NOMA manifests itself as a promising technology for increasing spectral efficiency and fairness in next-generation communication systems.

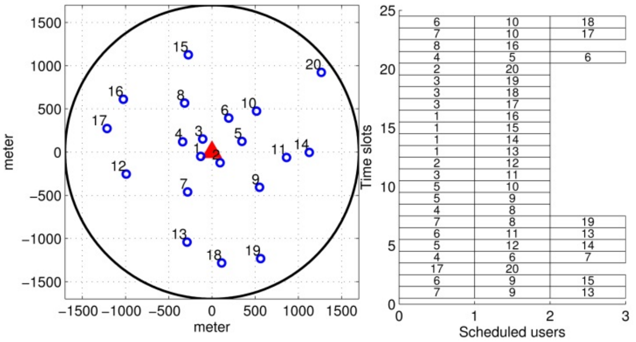

Fig. 3: An instance of transmission schedule

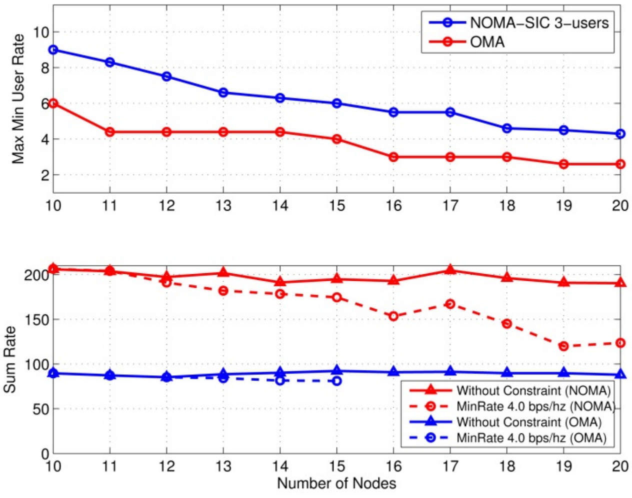

Fig. 4: Performance benefits of NOMA

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Activities

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2015 Asia-Pacific International Symposium on Electromagnetic Compatibility (APEMC 2015)

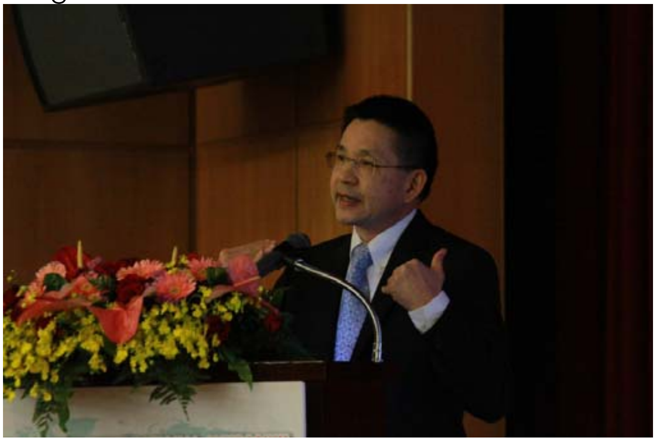
The 2015 Asia-Pacific International Symposium on Electromagnetic Compatibility (APEMC 2015) was successfully held on May 25-29 at the Grand Hotel, Taipei, Taiwan. This international symposium was organized by National Taiwan University (NTU) and the IEEE EMC Taipei Chapter, and was co-organized by the Bureau of Standards, Metrology & Inspection (BSMI) and Yuan Ze University, with the help from many academic and industrial organizations. People actively involving in organizing the conference include Prof. Pan-Chyr Yang (Honorary Chair of the symposium and President of NTU); Dr. Ming-Jong Liou (Co-Honorary Chair of the symposium and Director General of BSMI); Prof. Tzong-Lin Wu (General Chair, Director of the Graduate Institute of Communications Engineering of NTU, and former Taipei EMC Chapter Chair); Dr. Ding-Bing Lin (Technical Program Committee Chair, a professor of the Electronics Engineering Department, National Taipei University of Technology (NTUT), and current Taipei EMC Chapter Chair); and many other internationally renowned EMC activists and scholars. APEMC has been known as one the three greatest international EMC conferences. Since the first APEMC symposium held in Taiwan in 2005, this conference has steadily and robustly grown year by year. APEMC 2015 has reached an outstanding record of 256 paper submissions (among which 198 were published in oral or poster sessions), with 447 attendees coming from 22 countries.

The conference was opened on May 26 by Prof. Pan-Chyr Yang (President of NTU), Dr. Ming-Jong Liou (Director of BSMI), Dr. Robert Scully (President of IEEE EMC Society), and Prof. Tzong-Lin Wu (General Chair of the symposium). They all wished that the high-quality technical program of the symposium can expedite the development of more advanced EMC technology.

Invited guests are shown after the open ceremony in APEMC .

Keynote Speech

Right after the four short welcome speeches in the opening ceremony, Dr. Wen-Hann Wang, Intel Corporate Vice President and Managing Director of Intel Labs, delivered the first keynote speech, titled "Inventing a Smarter Future: Intelligence Everywhere." In this keynote, Dr. Wang brilliantly made prediction on the future development of the IC industry. He believed that the fast growing computing capabilities and smarter-than-before intelligence of new-generation ICs will lead to a more connected world—between devices and human beings—in the future. This will dramatically change our living styles, from transportation to living environment.



Dr. Wen-Hann Wang is shown presenting his keynote speech titled "Inventing a Smarter Future: Intelligence Everywhere" in APEMC 2015.

Dr. Nicky Lu of Etron Technology, after addressing on "A perspective on Integrated Circuits in Semiconductors: Technology and Industry," is shown with Prof. Tzong-Lin Wu .

In the second keynote speech, Dr. Nicky Lu, Chairman and CEO of Etron Technology, addressed the topic "A perspective on Integrated Circuits in Semiconductors: Technology and Industry," which is about how IC industries should proceed in the era that Moore's Law is facing physical limitations. Dr. Lu believed that the miniaturization of ICs will eventually encounter problems that are difficult, or even impossible, to solve. Under the challenging physical limitations, a circuit with a width of only 10 atoms cannot be

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stably manufactured because such a small photo mask is not yet reliable. In addition, with a circuit of such a small size, the conductor must have a large resistance and the gate in a MOSFET cannot completely turn off, leading to undesirable leaky current. These results will cause high power consumptions and poor signal-to-noise ratios. Furthermore, when circuits become so small, EMC problems will deteriorate, which is one of the problems that this symposium has focused on.

During the lunch time of May 27, the third keynote speech on "Building Stunning Client Devices" was delivered by Mr. James B. (Jay) Kirkland Jr., Vice President in the Client Computing Group (CCG) and General Manager of reference systems and technology at Intel. He emphasized that, in the next decade of exploding growth in high-speed signal transmission, both industry and academia will face the bottleneck predicted by Moore's Law. If no breakthrough manufacturing technology appears in the near future, how to promote available products on the basis of the close connection between brand-new concepts and the client's need will become a key factor in dominating high-tech markets. Although the internet of things (IoT) is no longer a new idea nowadays, thus far no any single company can act as a leader in the IoT market yet. Using Intel as an example, Jay pointed out that pursuing the hardware breakthrough will end up with the challenge of how to dramatically renew manufacturing technology. Hence, as a proof of his viewpoint, he further brought up ASUS's Transformer Books, a product that does not rely on hardware breakthrough but simply combines two functionally different mobile devices. Regarded as a successful originality, this simple combination not only fulfills the customer's need but also creates a large market for ASUS itself.

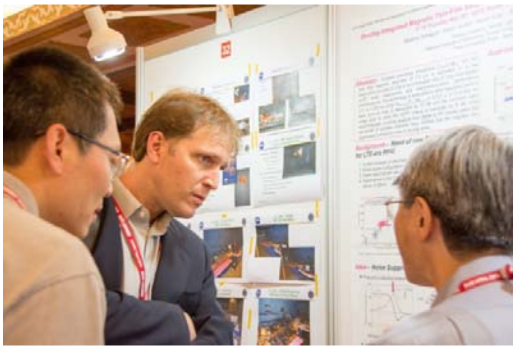
Mr. Jay Kirkland is shown demonstrating an ASUS Transformer Book during his keynote speech.

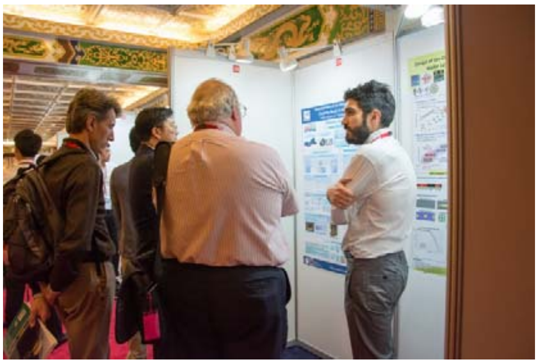
Best Paper Award (BPA) and Best Student Paper Award (BSPA)

Encouraging outstanding young scientists and promising students has been a tradition of APEMC; no exception this year. This symposium offers two academic achievement awards: best paper award (BPA) and best student paper award (BSPA). For each award, 10 finalists were first selected from almost one hundred participants and then reviewed by judges in an interactive poster session. The five BPA winners are Masahiro Yamaguchi (Japan), Flavia Grassi (Italy), Niels Kuster (Switzerland), Jianqing Wang (Japan), and Shih-Hsien Wu (Taiwan); the three BSPA winners include Heegon Kim (Korea), Chi-Kai Shen (Taiwan), and Chin-Yi Lin (Taiwan). The research works of these awards covered quite a broad range of areas, including high-frequency EMC, filter design, wearable devices, and noise protection for space shuttles. In order to thank the winners' academic contributions, both BPA and BSPA prizes were granted during the conference banquet on May 28.

Paper Presentations on Versatile Research Areas

In the four-day technical program, scholars and students from all over the world shared their research outcomes and achievements in many rapidly growing EMC-related areas; experts and specialists from industry presented many new technologies that are different from academic viewpoints. Relevant topics include EMC measurement standards, EMC environment, transient EMC, system-level EMC, IC-level EMC, automotive EMC, antennas and EM waves, packaging EMC, signal integrity, power integrity, wireless-communication EMC, computational EMC, biomedical electromagnetics, wireless charging, space EMC, etc.





Scenarios relevant to oral sessions (top four pictures) and poster sessions (lower two pictures) in APEMC 2015.

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Activities

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On May 28, the conference banquet held in Chinese-culture-enriched Grand Ball Room was opened by Chinese style dances performed by dancing-majored students from National Taiwan University of Arts. After the dance performance, Prof. Jin-Fu Chang (Chair of the International advisory committee (IAC) of the this symposium and President of Yuan Ze University) and Prof. Ruey-Beei Wu (Vice Chair of IAC and Chief Executive Officer of Institute for Information Industry) represented the Taiwan academia and industry, respectively, to thank attendees from abroad.

Besides the best paper and best student paper awarding ceremony, and besides the report delivered by Prof. Ding-Bing Lin, the symposium also presented a Lifetime Achievement Award to Prof. Song-Tsuen Peng, who initiated the APEMC in Taiwan in 2005. Since 2008, APEMC has been held in many countries other than Taiwan, including Singapore, Japan, China, Korea, and Austrailia. This conference has become a very important international gathering supported by both academia and industry. Without Prof. Peng's great effeort 10 years ago, we would not see the current blooming status.

Speeches delivered by the IAC Chair,
Prof. Jin-Fu Chang, in the conference banquet.

Speeches delivered by the IAC vice Chair,
Prof. Ruey-Beei Wu, in the conference banquet.

In the May 29 luncheon, people were all looking forward to the lucky draw activity. ASUS donated four recently announced ASUS Zenfones and six ZenPowers. Before the end of the luncheon, Ansys unexpectively added an Apple iPad Air as an additional prize, making the ambience high.

However attractive, APEMC 2015 finally came to an end two hours after the luncheon. It will be held in Shenzhen, China next year. Farewell !

Dr. Robert Scully, President of IEEE EMC Society, presented
Lifetime Achievement Award to Prof. Song-Tsuen Peng.

Prof. Peng presented in the conference banquet.

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