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In this issue

Technology Developed in GICE

Advanced Entropy Coding Techniques

from Communication and Signal Processing Group

Introduction

Entropy coding, such as the Huffman code, the static arithmetic code, and the adaptive arithmetic code, plays a very important role in image and video compression.

The Huffman code was developed in 1950s. In JPEG, Huffman coding is applied to encode DC differences and the AC coefficients. However, since it encodes each input independently, its coding efficiency is not as good as that of arithmetic coding [1]. There are two types of arithmetic coding: static arithmetic coding and adaptive arithmetic coding.

When performing static arithmetic coding, first, the probability distribution of the input data is given. Then, the upper bound and the lower bound of the probability range are adjusted adaptively according to the input data. Static arithmetic coding can achieve high coding efficiency than Huffman coding, however, one needs extra memory to record the probability distribution of the input data. The other type of arithmetic coding, adaptive arithmetic coding [2], does not have to record the probability of the input data. Instead, it applies a table, which is named as the frequency table (denoted by $F[n]$), to record the probability distribution of the data (denoted by X). The probability of X = n is calculated from

P(X = n) = F[n]/sum (F[n]). (1)

Initially, we set F[n] = 1 for all n. Then, we adjust the value of F[n] during the encoding process:

F[n] ⇦ F[n] +1 if X[m] = n. (2)

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GICE Honors

Congratulations

-2015 QS World University Rankings by Subject-

National Taiwan University is the 15th in the world in Electrical & Electronic Engineering.

Prof. Kwang-Cheng Chen

「103 MOST Outstanding Research Award」

Prof. Homer H. Chen

「103 MOST Outstanding Research Award」

Prof. Jing-shown Wu

「Institute of Information & Computing Machinery (IICM) Medal of Honor 2014」

Message from the Director

Tzong-Lin Wu

Professor & GICE Director

GICE is responsible to be the leader in education and to maintain our high level of research in communication engineering field in Taiwan and worldwide. In this periodical, we publish outstanding researches from prof. Jian-Jiun Ding and prof. Kun-You Lin, hoping you can gain benefits from these two research results.

There is a major breakthrough to share to all friends concerning the improvement of engineering field. The British Quacquarelli Symonds (QS) Company has released its 2015 QS World University Rankings by Subject which is based on an evaluation of 3,551 universities. National Taiwan University is the 15th in the world in Electrical & Electronic Engineering, marking its best performance ever.

Please enjoy the latest issue and you will have an instructive read.

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Then, F[n]/sum (F[n]) will be closer and closer to the true probability distribution of the input data as m grows.

New Ways for Adjusting the Frequency Table

However, the way to adjust the frequency table of adaptive arithmetic coding can be generalized in several ways. First, instead of adding the value of F[n] by 1, one can add it by a function growing with m:

$F[n] \Leftarrow F[n] + A[m]$ if $X[m] = n$ (3)

For example, one can set A[m] as the linear form or the geometric form as follows:

linear form: $A[m] = a + bm$, (4)

geometric form: $A[m] = c \cdot d^m$ (5)

where a, b, c, and d, are adjustable constants (a, b, c > 0 and d > 1). If one applies the two ways to adjust the frequency table, then the input data that is near to the current one will have a higher effect on the frequency table.

Moreover, instead of initializing the frequency table by F[n] = 1 for all n, one can initialize F[n] by a normal distribution function or a Poisson distribution function.

Furthermore, one can also apply the technique of range adjusting to modify the frequency table. If X[m] = n, then not only F[n] but also the values of $F[n_1]$ where n_1 are near to n are changed:

$F[n_1] \Leftarrow F[n_1] + A[m]\, c_1 \exp(-\sigma(n_1 - n)^2)$ if $X[m] = n$ (6)

where c_1 is the inverse of the sum of $\exp[-\sigma(n_1 - n)^2]$ and $A[m]$ is defined the same as (4) and (5). In the case where $n > 0$ and the probability of $X[m] = n$ decreases with n, one can set

$F[n_1] \Leftarrow F[n_1] + A[m]\, c_2 \exp(-\sigma(n_1 - n)^2/n^2)$ (7)

where c_1 is the inverse of the sum of $\exp(-\sigma(n_1 - n)^2/n^2)$. We apply the technique of range adjusting in (6) or (7) because we think that the probability of $X[m] = n$ is close to that of $X[m] = n_1$ if n is near to n_1.

Furthermore, for the case of context modeling, since it may happen that the frequency table of a context may be closely related to the frequency tables of other contexts, it is proper to perform mutual learning. That is, suppose that $F_j[n]$ is the frequency table of the j^{th} context. If $X[m] = n$, then not only $F_j[n]$ but also $F_q[n]$ are adjusted if the j^{th} context and the q^{th} context have similar properties:

$F_q[n] \Leftarrow F_q[n] + C[j, q]\, B[m]$ (8)

if $F_j[n] \Leftarrow F_j[n] + B[m]$

where $B[m]$ is the adjusting step for the j^{th} context and $C[j, q]$ is proportional to the correlation between the j^{th} context and the q^{th} context.

Simulations

We give some simulations to show the effect that applies adaptive arithmetic coding using the proposed frequency table adjusting method to encode the bit plane in the JPEG2000 process. The standard JPEG200 applies embedded block coding with optimized truncation (EBCOT) [3]. It is also a modification form of arithmetic coding and has very high coding efficiency. In Table 1, we show the performances that apply proposed adaptive arithmetic coding method in the JPEG200 process to encode 7 images and

Images	Lena	baboon	airplane	Tiffany	splash	sailboat	house
EBCOT	68,560	205,100	51,900	75,820	42,154	145,.631	80,047
Proposed Method	67,066	201,025	51,014	74,434	41,561	142,899	78,643

Table I. Number of Bytes When Using EBCOT the Proposed Frequency Table Adjusting Method in the JPEG2000 Process for Image Compression.

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compare them with the results where the EBCOT technique is applied. The results in Table 1 show that the proposed frequency table adjusting method can indeed improve the coding efficiency of arithmetic coding and is useful for data compression.

[1] I. H. Witten, R. M. Neal, and J. G. Cleary, "Arithmetic coding for data compression," Communications of the ACM, vol. 30, pp. 520-540, 1987.
[2] N. Kuroki, T. Manabe, and M. Numa, "Adaptive arithmetic coding for image prediction errors," IEEE International Symposium on Circuits and Systems, vol. 3, pp. 961-964, 2004.
[3] C. Christopoulos, A. Skodras, and T. Ebrahimi, "The JPEG2000 still image coding system: an overview," *Consumer Electronics, IEEE Transactions on*, 46.4, pp. 1103-1127, 2000.

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CMOS Power Amplifiers

from Electromagnetics Group

- K-band CMOS cascode power amplifier using optimal bias selection methodology [1]

For a cascode power amplifier (PA), the common-gate (CG) transistor is saturated at a smaller input power compared with the common-source (CS) transistor. Therefore, the difference between the 1-dB compression power (P1dB) and the output power with peak power added efficiency (PAE) becomes huge, resulting in the low PAE value at P1dB. To improve the PAE of a cascode PA for the power back-off from P1dB, the CG transistor has to be designed to saturate simultaneously with the CS transistor.

Figure 1 shows the optimal bias calculation for cascode cell.

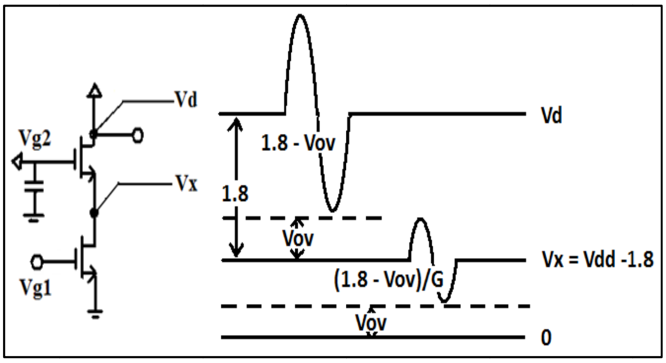

Fig. 1. Optimal bias calculation for cascode cell.

The maximum amplitude of Vd is (1.8-Vov). If the voltage gain of the CG device is G, amplitude of Vx is (1.8 Vov)/G. The voltage between the drain and the source of the CG device is 1.8 V. For simultaneous saturation for the CG and the CS devices, the voltage between drain and source of CS device is (1.8-Vov)/G+ Vov. The bias voltage of the cascode configuration can be calculated by

$$V_d = V_{ov} + \frac{1.8 - V_{ov}}{G} + 1.8 \qquad (1)$$

and

$$V_{g2} = V_{ov} + \frac{1.8 - V_{ov}}{G} + V_{gs} . \qquad (2)$$

Figure 2 shows the chip photo of the two-stage cascode PA using the proposed optimal bias selection methodology.

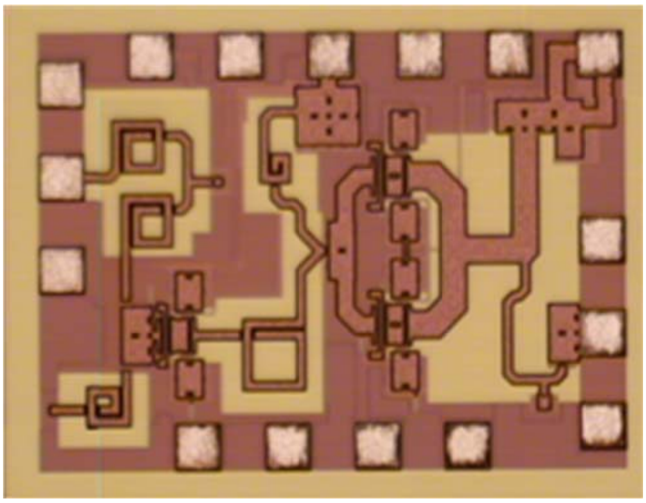

Fig. 2. Chip photo of the two-stage PA using the proposed optimal bias selection methodology.

The PA is fabricated by 0.18- m CMOS process, and the chip size is 0.47 x 0.65 mm^2. The measured power performance at 21 GHz is shown in Fig. 3. The cascode PA is biased at V_{g1}=0.9 V, V_{g2}=1.8 V and V_d=2.7 V. The output power at peak PAE is 18.1 dBm, and the P1dB is 16.8 dBm. The peak PAE and the PAE at P_{1dB} are 18.9% and 15.5%, respectively. The proposed bias selection method can make the CS and CG devices of the cascode PA reach saturation simultaneously and obtain excellent PAE at P_{1dB}.

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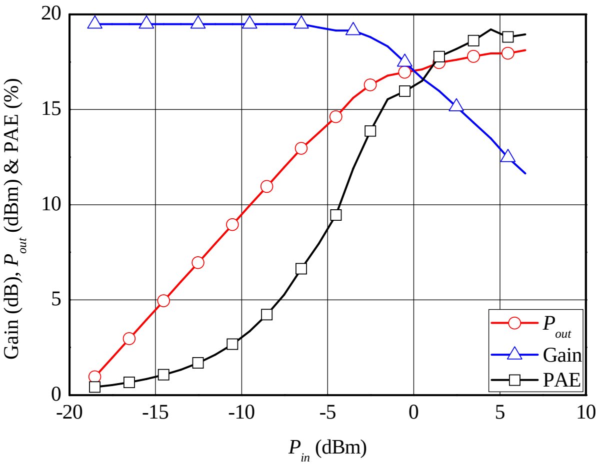

Fig. 3. Measured power performance of the two-stage PA.

- Phase-delay cold-FET pre-distortion linearizer for millimeter-wave CMOS PAs [2]-[3]

Cold-FET pre-distortion linearizer has advantages of low loss and no dc power consumption. To improve the cold-FET pre-distortion linearizer performance in CMOS process, phase-delay cold-FET pre-distortion linearizer is proposed as shown in Fig. 4.

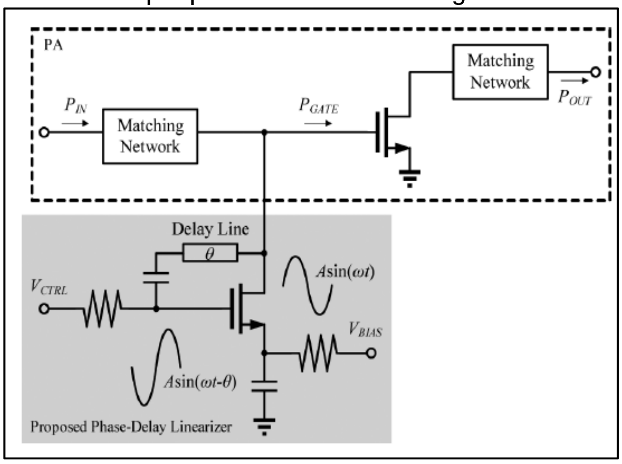

Fig. 4. Schematic of a PA with the proposed phase-delay cold-FET pre-distortion linearizer.

In order to verify the proposed concept, a *V*-band and a *K*-band CMOS PAs are developed. Fig. 5 shows the chip photo of the *V*-band PA with the proposed 90° phase-delay pre-distortion linearizer. The chip is implemented by 90-nm CMOS process, and the chip size is 0.248 mm². The proposed linearizer is placed at the input of the power stage, and the 90° phase-delay is achieved by a microstrip line.
The measured power performance of the *V*-band PA is shown in Fig. 6. The P_{1dB} and the corresponding PAE are improved from 11.8 to 13.7 and from 8.9% to 14.3%, respectively. The output power with -40 dBc IMD3 is extended from -0.6 dBm to 4.2 dBm.

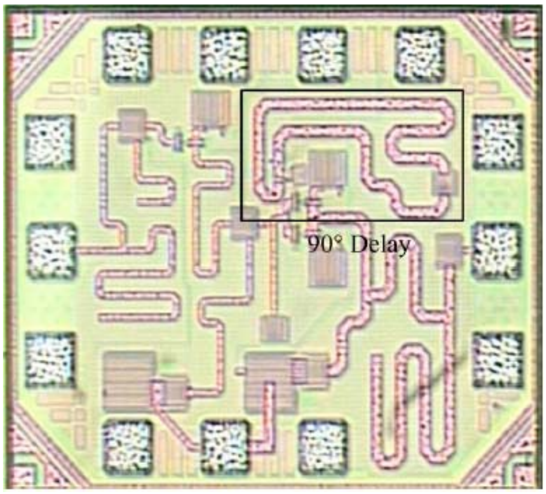

Fig. 5. Chip photo of the V-band PA with the proposed 90° phase-delay cold-FET pre-distortion linearizer.

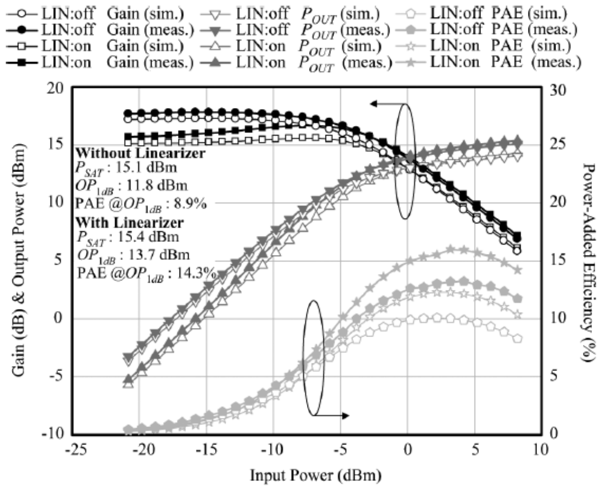

Fig. 6. Measured performance of the V-band PA.

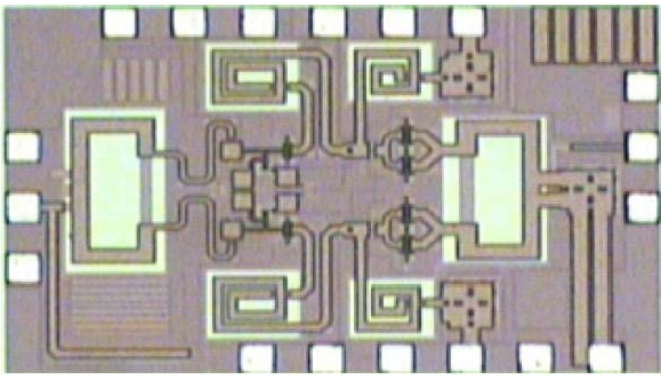

Fig. 7. Chip photo of the K-band PA with the proposed 180° phase-delay cold-FET pre-distortion linearizer.

For lower frequency such as *K*-band, the delay line for the phase-delay pre-distortion linearizer bulky. Therefore, transformer-combined topology is selected to not only increase the output power but also implement the 180° phase-delay pre-distortion linearizer. Fig. 7 shows the chip photo of the proposed 0.18- m CMOS transformer-combined PA with 180° phase-delay pre-distortion linearizer.

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The chip size is 0.566 mm^2. The measured power performance, of the *V*-band PA is shown in Fig. 8.

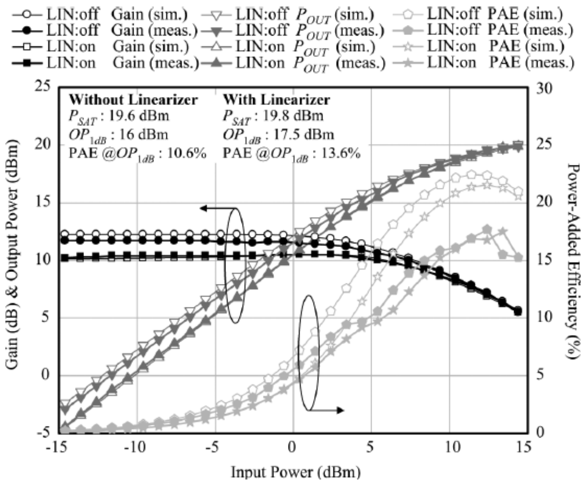

Fig. 8. Measured power performance of the K-band PA.

The P_{1dB} and the corresponding PAE are improved from 16 to 17.5 and from 10.6% to 13.6%, respectively. The output power with -40 dBc IMD3 is extended from 7.8 dBm to 10.8 dBm.

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[2] Yu-Chung Hsu, Kun-Yao Kao, Jui-Chih Kao, Tzung-Chuen Tsai, and Kun-You Lin, "A 60 GHz CMOS power amplifier with modified pre-distortion linearizer," in *IEEE MTT-S Int. Microw. Symp. Dig.*, June 2013.

[3] Kun-Yao Kao, Yu-Chung Hsu, Kuan-Wei Chen, and Kun-You Lin, "Phase-delay cold-FET pre-distortion linearizer for millimeter-wave CMOS power amplifiers," *IEEE Trans. Microw. Theory Tech.*, vol. 61, no. 12, pp. 4505-4519, Dec. 2013.

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Activities

The 5th Conference on the Talent Cultivation Program for Smart Living Industry

In April 25, 2015, the Communication Research Center co-host the 5th Conference on the Talent Cultivation Program for Smart Living Industry, sponsored by MOE. This talent cultivation program was a 4-year program with focuses on three fields: Sustainable Smart Living Space, Smart Health and Medical Care, and Culturally-oriented Living Technology, and its objective is to cultivate university students and teachers through interdisciplinary training and equipping them with the ability to fit the future needs of emerging smart-living industry. In the last 4 years, about 200 teachers from more than 30 universities and colleges have participated various course enhancement projects and developed novel services models with their field services teams.

In the Sustainable Smart Living Space, this program has emphasized the significance of environmental issues in this subfield, covering micro and macroscopic spaces, ranging from a room, house, community, and city to the entire country. In the area of Smart Health and Medical Care, medical care was considered as a core technology and infrastructure facilitates clearer communication between the care service provider and consumer.

Exhibition booths from several Smartliving service teams, with topics ranging from energy saving to culture-oriented technology-marketing.

Cooperation among medical care center units, such and hospitals or care centers, have facilitated student internship and services in the field.

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Activities

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Meanwhile, in the area of Culturally-oriented Living Technology, the project teams have explored local culture, history, and industry in-depth will cultivate cultural sensitivity and awareness in students. After acquiring insight of local culture, students can apply their observations in specializing and making smart living technology appealing to customers. As a bridge between the Ministry of Education and the entire program, the Program Office in the Communication Research Center of NTU has been responsible for program orientation, planning, organizing, performance evaluation, and coordinating the whole program including all of the subprograms.

All speakers in this annual conference were selected and invited by the program office, either due to their excellent performance in courseware designs, or based on the awards for their significant contributions to the local community through community services with high social concerns. There were more than 20 exhibition booths for project teams to exhibit their hands-on deliverables. Prof. Tsai-Yen Lee, the head of the department of information and technology education of MOE, had delivered the opening speech of this conference and also awarded the elite instructors of 2014. In total, this conference has attracted more than 160 participants from various universities and industrial partners.

Group photo of invited speakers, awarded instructors, MOE officials, and members of the Talent Cultivation Program Office for the Smart living Industry.

2nd NGMN and 5G Technology Trends Forum (Spring Forum)

Next Generation Mobile Network (NGMN) Alliance is one of the most important broadband mobile alliances worldwide.

2nd NGMN and 5G Technology Trends Forum in Taipei (Spring Forum)

Different from other international standard bodies such as 3GPP, NGMN Alliance focuses on defining, consolidating and communicating operator requirements to ensure that customer needs and expectations on mobile broadband are fulfilled.

NGMN Taiwan Team, formed by Graduate Institute of Telecommunications, National Taiwan University and National ChiaoTung University supported by Ministry of Education, has been participated in various NGMN activities and international coalition organizations. The team has officially presented 3 key contributions on “Fog Network: F-RAN for future IoT Applications in Wireless 5G”, “Smart Data Pricing”, and “Licensed Shared and Licensed Exempted Spectrum Access for the Next-Generation Mobile Networks”, in the NGMN Forum which was held in Singapore in January 2015. The presentations were well received by the audience. The team has also submitted 4 proposals including “Fog Network

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and Computing for Wireless 5G", "Spectrum Sharing & Management", "Business Models and IPRs for IoT Services & Applications in Wireless 5G Environment", and "Customer Use Case Study" to the NGMN Alliance for being considered as a 2015 NGMN Work Program for the Board. The Work Program will define 5G requirements and fundamental technologies, and is regarded as the ticket to 5G standardization.

NGMN Advisory Forum in Singapore

On 10 April 2015, NGMN Taiwan team held "2nd NGMN and 5G Technology Trends Forum (Spring Forum)" at NTU Barry Lam Hall. This forum focused on 5G White Paper published by NGMN Alliance in March 2015 and attracted nearly ninety experts from domestic academic community and industrial institutes. In the forum, each team member gave a brief talk on 5G visions and Use Case, Requirements, Technology and Architecture, Spectrum Access, and IPR respectively. The team also invited Prof. Bingli Jiao of Peking University, Prof. Lingyang Song of Peking University, Prof. Ning Ge of Tsinghua University and Prof. Zhiyong Feng of Beijing University of Posts and Telecommunications to the Spring Forum to share their latest 5G research so as to strengthen cross-strait cooperation and to leverage each other on 5G technologies. Another goal of this forum is to engage Taiwan ICT and academic community, to understand the technological trend and business development of 5G so as to establish a close cooperation. Through these activities and participation, Taiwan Team is becoming a main academic driving force in this region.

Brainstorming Workshop on 5G Wireless

The Fifth Brainstorming Workshop on 5G Wireless was held at the National Taiwan University, Taipei, on April 11 - 12, 2015. Started in 2013 to stimulate discussion and cooperation between researchers in China and Taiwan working on the research and technology development of the fifth generation (5G) mobile wireless networks, this semi-annual workshop has quickly become one of the most important events in the greater China area, including China, Taiwan, Hong Kong, Macau and Singapore, dedicated to the R&D of the 5G mobile wireless networks. The fifth workshop attracted over 100 researchers and engineers to share their ideas on six important 5G topics: Radio Access Technology, Spectrum Management, Fog Networking and C-RAN, Radio Resource Management, Network Economics, and Heterogeneous Networks. Each topic was introduced by a few highlighting presentations given by leading 5G researchers from China, Taiwan, Hong Kong, Macau and Singapore which sparked brainstorming discussion among all attendees.

The Fifth Brainstorming Workshop on 5G Wireless was opened by Prof. Kwang-Cheng Chen (National Taiwan University, Taiwan, IEEE Fellow), Prof. Xiaohu You (Southeast University, China, IEEE Fellow) and Prof. Char-Dir Chung (National Taiwan University, Taiwan, IEEE Fellow).

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Group photo of the attendees of the 5th Brainstorming Workshop on 5G Wireless in front of the Barry Lam Hall of the National Taiwan University where the workshop took place.

On the first day, the discussion sessions on Radio Access Technology, Spectrum Management, Fog Networking and C-RAN, Radio Resource Management, Network Economics, and Heterogeneous Networks were chaired and moderated by Prof. Bingli Jiao (Peking University, China), Prof. Chun-Ting Chou (National Taiwan University, Taiwan), Prof. Ai-Chun Pang (National Taiwan University, Taiwan), Prof. Zhiyoung Feng (Beijing University of Posts and Telecommunications, China), Prof. Jianwei Huang (The Chinese University of Hong Kong, Hong Kong), Dr. Sumei Sun (Institute for Infocomm Research, Singapore), respectively, with presentations given by researchers from The University of Macau, National Taiwan University, Tsinghua University (China), National Chiao Tung University (Taiwan), The Chinese University of Hong Kong, Xidian University (China), Beijing University of Posts and Telecommunications, National Tsinghua University (Taiwan), National Communications Commission of Taiwan, etc. The luncheon keynote speech was delivered by Prof. Tzi-Dar Chiueh (MediaTek-NTU Research Center, IEEE Fellow). The first day was concluded by the closing speech Prof. Russell Hsing (National Chiao Tung University, Taiwan, IEEE & SPIE Fellow) and the banquet.

Speech delivered by Prof. Char-Dir Chung (professor of GICE and Executive Secretary of BOST)

On the second day, feature speeches on full duplex, heterogeneous networks, cooperation communication, and small cell technologies were delivered by Prof. Bingli Jiao, Dr. Sumei Sun, Prof. Xiaofeng Tao (Beijing University of Posts and Telecommunications), and Prof. Tony Quek (Singapore University of Technology and Design), respectively.

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