NTU GICE Newsletter
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In this issue

Technology Developed in GICE

Beam-Aware Dormant and Scheduling Mechanism for mmWave 5G Systems

from Communication and Signal Processing Group

INTRODUCTION

The millimeter-wave (mmWave) communications have become inevitable in the next generation communication networks. The system operates at a band whose frequency is above 30 GHz. The high operating frequency results in the high propagation loss; therefore, in order to compensate the extreme loss, devices are equipped with large antenna arrays for beamforming (BF). However, the increasing number of antennas and corresponding radio frequency (RF) modules also makes the power consumption higher, which especially has a big impact on the user equipment (UE). Besides, 3rd Generation Partnership Project (3GPP) also adopted UE energy efficiency as one of the key performance indicators (KPI) for 5G networks. In addition, beamforming also add directionality to the communication links between devices. The directionality decreases the interferences because of the narrowed transmitting and receiving angle, but this property also makes the design of the MAC procedure complicated. With this directionality, when the base station (BS) and the UE is communicating, it is important to keep the beams of BS and UE aligned through beam management, so both control signal and user data can be sent successfully.

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GICE Honors

Prof. Ching-Kuang C. Tzuang
2018 IEEE MTT-S Distinguished Educator Award

Prof. Tzong-Lin Wu
2018 joint IEEE EMC and APEMC Symposiums「Best SI/PI Paper Award & Best Student Paper Award」

Message from the Director

Hsuan-Jung Su

Professor & GICE Director

With the new semester coming, we are excited to have a new professor joining GICE. Prof. Chun-Lin Liu is a GICE graduate. After GICE, Prof. Liu received the Ph.D. degree from Caltech and was awarded the Ben P. C. Chou Doctoral Prize for his outstanding dissertation. Let us welcome Prof. Liu!

In this issue, we invite Prof. Hung-Yu Wei and Prof. Kun-You Lin to share their recent research results. Please enjoy the reading and we hope that you will find their research interesting.

In the Corner of Student News, we invite Alessandro Galeazzi, who is in the double degree program between GICE and University of PADOVA, to share his experience. GICE has established double degree and exchange programs with quite a few internationally renowned universities. We welcome international students to join or visit GICE!

Technology *(Continued from page 1)*

Reference signal (RS) is widely used in wireless communications. Mostly, the purpose of sending RS is to measure the wireless channel. This kind of RS is also known as CSI-RS. After the measuring of the RS, the devices then generate measurement reports for further control decisions, such as the selection of modulation and coding scheme (MCS). Therefore, the accuracy of the measurements is important to make proper decisions. However, the directionality of beamformed links in mmWave communications would add more measurement delay than traditional communications. On both BS and UE side, a beam sweeping procedure is performed for alignment, and the procedure takes numbers of timeslots. The outdated CSI estimation could seriously decrease the performance of the transmissions. In this work, we proposed a beam-aware dormant and scheduling mechanism, which enables UE to sleep between the receptions of RS and to communicate with valid measurement results.

Beam-aware Dormant and Scheduling Mechanism

Fig. 1 shows the timeline of the beam sweeping procedure. In (a), we can see that the BS transmits the CSI-RS periodically for channel measurement on UE side. For example, in (b), after RS 2 is sent, the UE has to report the channel quality indicator (CQI) to the BS. Then, within the channel coherence time, the transmission is considered to be more reliable. If the CQI is outdated, it is required to perform the next measurement. Therefore, the proposed mechanism is to allow UEs to be dormant within the time of CQI outdated. For example, in (c), if a UE on beam 2 receives the RS 2, it stays awake for downlink data only in the channel coherence time, and then goes to sleep. In the proposed mechanism, we defined a variable called "schedulable time" to model this behavior. BS can configure the length of schedulable time for UEs, then the UE can go to sleep according to the RS reception and schedulable time configuration. Fig. 2 shows an example that how schedulable time works in the proposed mechanism. The length of the schedulable time is set to T timeslots and the RS is received at t1 timeslot. The UE uses one timeslot to report the measurement result, and then enters the schedulable time. During the schedulable time, the BS is possible to schedule downlink data to the UE. After the end of the schedulable time, the UE goes to sleep.

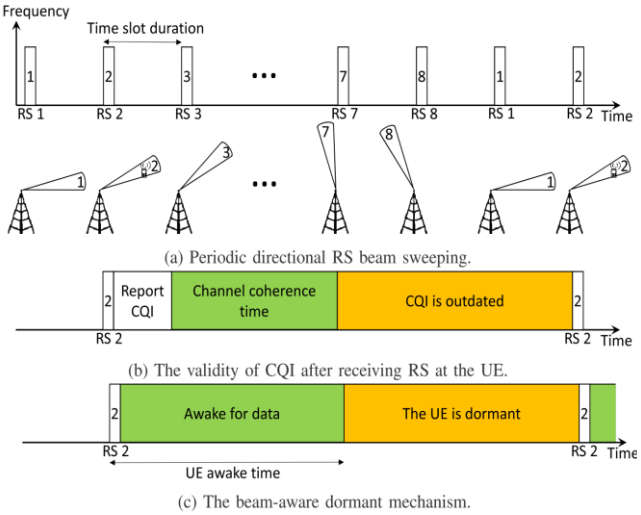

Fig. 1: Beam-aware dormant and scheduling algorithm

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Technology *(Continued from page 2)*

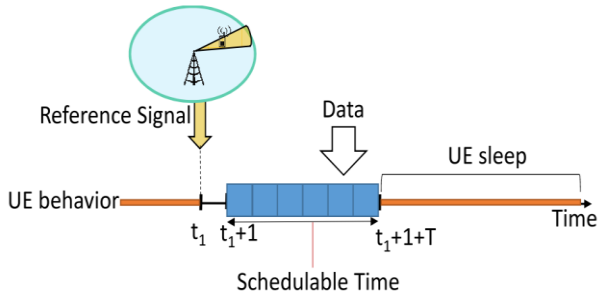

Fig. 2: UE power state transition after the reception of reference signal

Result and Discussion

Fig. 3 shows the result of the system throughput. We can see that our analytical model well matches the simulation result. We compare our proposed mechanism with the LTE scheduling mechanism. We can see that the proposed mechanism has better performance than the baseline. The reason is that our proposed mechanism takes the validity of the measurement into consideration. Besides, we can also see that a proper configuration of schedulable time also gives a better system throughput. Fig. 4 shows the power saving ratio of the proposed mechanism. We can see that the power saving ratio decreases when the length of schedulable time increases. The reason is that the UE stays awake longer when the schedulable time is longer.

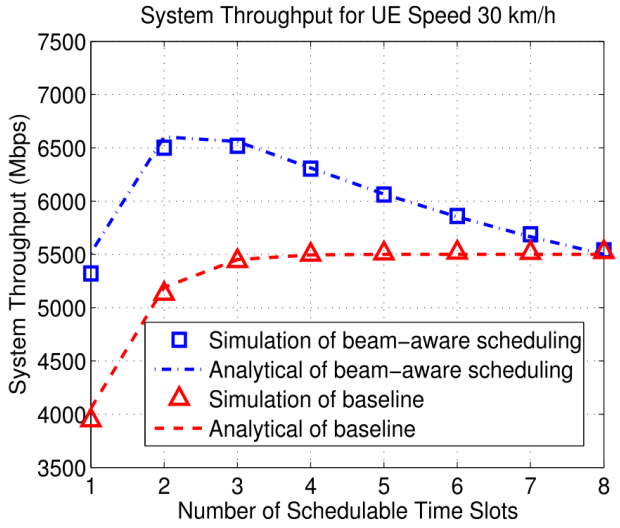

Fig. 3: System throughput for 10 UE with 30 km/h speed

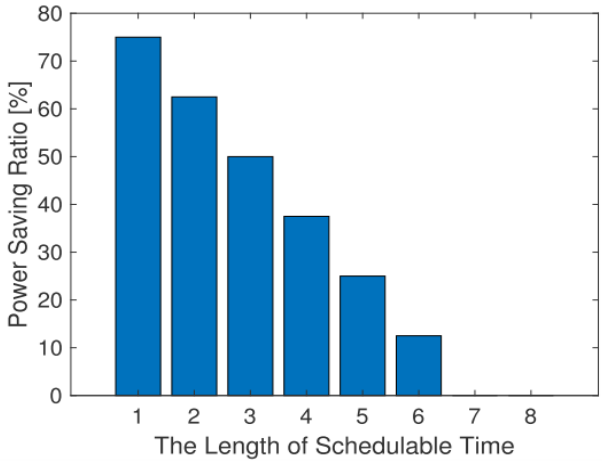

Fig. 4: Power saving gain

Conclusion

Millimeter wave communication is one of the most important technology in the next generation of wireless communication network. In order to compensate the high pathloss of the mmWave signals, the beamforming technique is applied and make the links become directional. Besides, the power consumption of the circuits also increases. The directionality is a critical problem for the transmission of the reference signals since the beam sweeping procedure increases the latency and outdated measurements. We proposed a beam-aware dormant and scheduling mechanism for mmWave communication systems. The results show that the system throughput is enhanced by 29.4%. Besides, the proposed of "schedulable time" also provides the opportunity of sleeping for UEs. Therefore, the UEs can meet the high requirement of the power efficiency.

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Technology

A 20 GHz Power Amplifier with IM3 Distortion Cancellation by Load-Split Derivative Superposition

from Electromagnetics Group

A load-split derivative superposition (DS) linearization technique applied to a K-band CMOS power amplifier (PA) is proposed. Conventional DS amplifier as shown in Fig. 1(a) is usually used to cancel high-order trans conductance nonlinearity. However, while the DS amplifier is applied to higher frequency such as K-band, a trade-off between the effective zero gm3 region and the input capacitance is necessary. Large input capacitance results in the drawback of power gain degradation at high frequency due to the low input impedance. Therefore, the application of the DS amplifier is limited.

In order to solve this problem, a common-drain (CD) buffer is used as an input replica to split the extra loading from the auxiliary DS path as shown in Fig. 1(b). The extra input capacitance of the auxiliary path is only contributed by the CD buffer (M4), therefore a low input impedance can be maintained even large transistors are used for the auxiliary path.

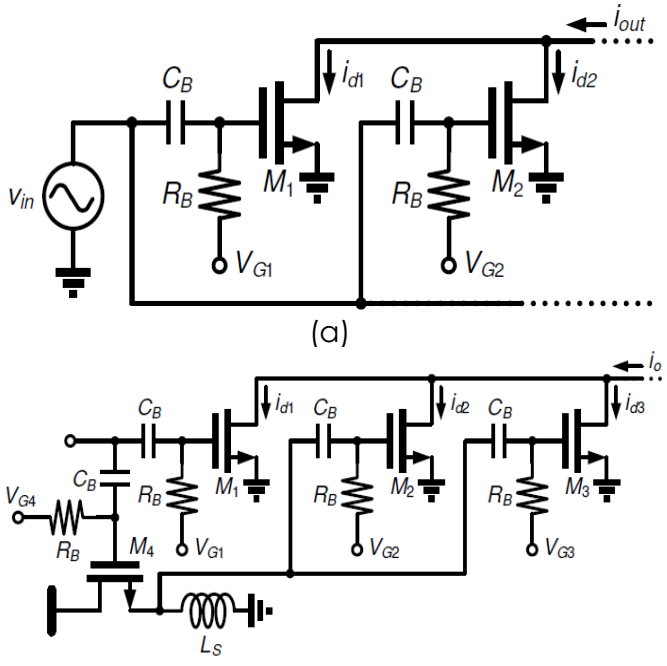

Fig. 1. (a) Conventional , and (b) proposed load-split derivative-superposition amplifier.

Fig. 2 shows the schematic and chip photo of the K-band two-stage power amplifier using the proposed load-split derivative-superposition for the power stage. This amplifier is implemented by 0.18- m CMOS process, and the chip size is 0.76 x 0.44 mm2 including all testing pads.

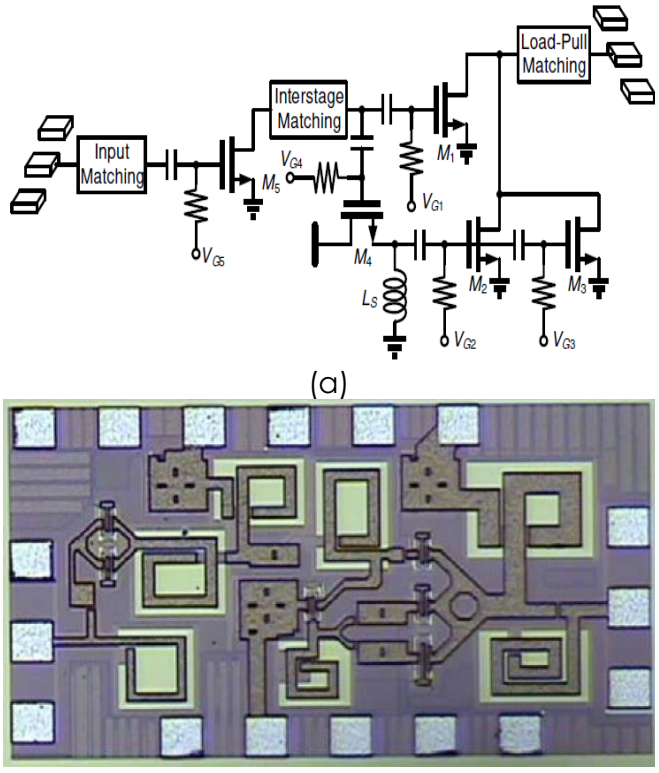

Fig. 2. (a) Schematic, and (b) chip photo of the K-band two-stage power amplifier using the proposed load-split derivative-superposition for the power stage.

The simulated and measured power performance at 20 GHz of the proposed power amplifier is shown in Fig. 3(a). The OP1dB and the corresponding PAE are 14.3 dBm and 11%, while the peak PAE is 13% with 15.6-dBm output power. Fig. 3(b) shows the simulated and measured IMD3 performance under 20±0.005 GHz 2-tone test. The measured maximum output power with IMD3 below -30 dBc is 11.9 dBm, and the sweet-spot occurs at 10-dBm output power. The measured results verifies the proposed load-split DS technique is effectively improved the performance of the conventional DS technique.

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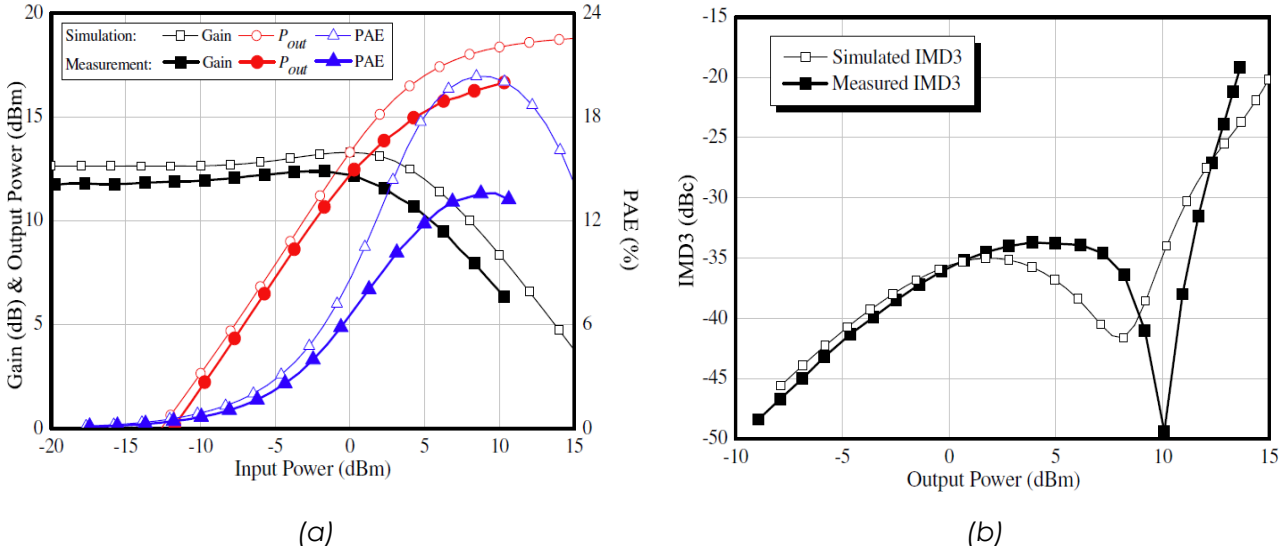
Technology *(Continued from page 4)*



(a) *(b)*

Fig. 3. Simulated and measured (a) power, (b) IMD3 performance of the proposed PA.

References

[63] Kun-Yao Kao, Hung-Yu Lin, and Kun-You Lin, "A 20 GHz power amplifier with IM3 distortion cancellation by load-split derivative superposition," in IEEE MTT-S Int. Microw. Symp. Dig., May 2016.

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Activities

- 5G & Beyond Announcement

The 5G & Beyond announcement was held at Barry Lam Hall, National Taiwan University on May 10th, 2018. The announcement was hosted by Prof. Tzong-Lin Wu, chairman of Graduate Institute of Communication Engineering, National Taiwan University and organized by GICE, NTU. Several outstanding guests are invited, including Mr. Jerry Shen, CEO of ASUS, Prof. Ming-Syan Chen, Dean of College of Electrical Engineering and Computer Science, NTU, and Prof. Ruey-Beei Wu, Distinguished Professor of EE Department, NTU.

There were 5 project achievements announced, the works of each project were also demonstrated at Barry Lam Hall. The 5 projects included "5G/B5G 38 GHz mmWave Transceiver System," directed by Prof. Tzong-Lin Wu, "5G/B5G Sub-6GHz Massive MIMO Experimental Platform," directed by Prof. Hsi-Tseng Chou, "5G/B5G Sub-6GHz RF Front End," directed by Prof. Shau-Gang Mao, "5G/B5G 60 GHz Beamforming Front-end System," directed by Prof. Kun-You Lin, and "VISSA : New Era Shared Spectrum Access Platform," directed by Prof. Shi-Chung Chang. These announcements showed great accomplishment of each project, and provided a great chance for the audience to experience the newest 5G technologies for themselves.

(Continued on page 6)

Activities *(Continued from page 5)*

A workshop of 5G was held in the afternoon, also in Barry Lam Hall. This workshop was composed of 5 topics, including "Development of Millimeter-wave RFICs and LTCC Modules," by Prof. Huei Wang, "Spectrum and RAN Sharing in the 5G Era," by Prof. Shi-Chung Chang, "5G/B5G mmWave Antenna Technology," by Prof. Hsi-Tseng Chou, "Hybrid Beamforming with RF Chain Allocation for Massive MU-MIMO Systems in the mmWave Band," by Prof. Hsuan-Jung Su, and "Smart Radio Applications for Wireless Communications," by Prof. Shau-Gang Mao. These topics perfectly covered every part of a wireless communication system, and make a great overview of 5G communication technologies.

Prof. Ruey-Beei Wu, TEMIAC Coordinator

Prof. Tzong-Lin Wu, chairman of Graduate Institute of Communication Engineering, NTU

The announcement presented several prominent achievements of 5G topics, accomplished by the exceptional members of National Taiwan University. The workshop provided a great chance for the audience to understand the novel 5G technologies. Along with this announcement, we hope that a stronger bond can be made between the industry and NTU, and lead Taiwan to a higher position of the communication world in the 5G era.

Mr. Jerry Shen, CEO of ASUS

Demonstrated Projects

Group Photo

Activities

The 2018 1st semiannual report of Taiwan Electromagnetic Industry-Academia Consortium: RFID system design and practical application symposium

The technology of Radio frequency identification (RFID) now appears to be everywhere in our daily life. It has application in a variety of fields and is tend to mature in these years. This time, many active researchers and engineers were gathered in the 2018 RFID system design and practical application symposium on the 1st of June, 2018 at the Barry Lam Hall, National Taiwan University (NTU) in Taipei, Taiwan to discuss the challenges currently facing and the possible future directions. The symposium was organized by Taiwan Electromagnetic Industry-Academia Consortium, High-Speed RF and mm-Wave Technology Center, NTU and the Department of Computer and Communication, JinWen University of Science & Technology and co-organized by the Department of Electrical Engineering, NTU, Graduate Institute of Communication Engineering, NTU, Industry Liaison Office, NTU, Department of Electrical Engineering, Feng Chia University, 5-G Industrial Technology Consortium and IEEE Council of RFID Taipei Chapter.

" After the days of internet and wireless network, RFID is probably one of the most important inventions and is the key for the concept "Internet of Things".", says Professor Ruey-Beei Wu. At this moment, he was also quite surprised to see the rapid growth of RFID after its appearance in 1979. "Nearly forty years have passed, and almost everyone and every object are connected via RFID. It is thus, and still a great challenge to tailor the RFID system for everyone's need." In the light of this, the symposium invites five distinguished speakers to share their experiences working with RFID. It covers a wide range of topics including "Measurement and Applications of RFID Systems", "Application of Multi-Antenna Systems with Diversity on RFID", "RFID transponder for Industry 4.0", "RFID and NFC antennas design" and "Experience share of RFID application".

After these talks, there was a panel discussion and the attendees were able to exchange their opinions and discuss the current issues in RFID with many experts from the academia and industry. Professor Tzong-Lin Wu shared some thoughts he had for the possible directions of RFID:"Only if the costs are rising in the way that the customers are still happy with, will the RFID grow." He was happy to see that the strong players in RFID are working together here in Taiwan. As one of the main organizers, professor I-Fong Chen also gave some comments: "It is clear that RFID makes our life better and it is important to make sure that we can transform the know-hows in the RFID design into real profits to support further design improvements. It is not enough if engineers are only experts for their building blocks. The mutual collaboration between different fields, especially between the academia and industry, is the real key to success."

Group Photo

Corner of Student News

Alessandro Galeazzi came from Italy and he got his Master Degree by joining double degree program via a collaboration agreement signed by NTUGICE and University of PADOVA.

I clearly remember when I heard about the possibility of a double degree program with NTU. Most of my class mates were discouraged because the program just started this year and there were no feedback. To me, this was an extra incentive to experience something different and face up to a new interesting challenge. Thus, I decided to enroll in the program and finally in September I landed in Taiwan. I knew really a little about Taiwan and all the information I had turned out to be almost useless. My idea of Taiwan was totally different on how things really are, and I am happy to say that this country is much more beautiful than I expected. At the beginning, everything was different, difficult to understand and miles away far from what I was used to. Fortunately, I found a good "Taiwanese mentor" in my roommate. He showed me Taiwan and Taiwanese people and I started to understand how much beautiful the Taiwanese culture is. At the beginning, I did not have a clear idea about how a night market looks like, which type of Taiwanese food I like or where I should buy things. Now, for example, I perfectly know which place makes the best dumplings and where to buy my favorite bubble milk tea. I really enjoyed in exploring as many places as possible and trying a lot of dishes so different from Italian cuisine and I was so impressed by the terrific food culture one can find in Taipei.

Unfortunately, I did not come here just for eating and having fun, but fortunately I found in my advisor and lab mates good guides for helping me in my Taiwanese academic career. I can say for sure that the differences in the didactic methods between NTU and University of Padova I had to face opened my mind and improved my skills; while the discussions I had with my lab mates boosted my personal growth. Now, I look to my experience in Taiwan as a crucial step of both my personal and academic development.

Fortunately, from time to time, I had the opportunity to travel around Taiwan. I could not image that such a small island can have so many beautiful hidden gems. I will always remember the journeys I had here as one of the best of my life. Surfing in Waiao, experiencing the food in Tainan, admiring the big Buddha in Kaoshiung will always be great memories in my mind, but nothing impressed me more than the Taroko gorge. If I could take something back from Taiwan, I would choose Taroko gorge for sure. Unfortunately, as all good things in life, my Taiwan experience will finish soon, but I am sure that what it left to me will last for my whole life, as I am sure that, one day, I will have the chance to come here again.

Futsal tournament I joined with the NTU EE football team.

Taroko gorge

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