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In this issue

Technology Developed in GICE

Dual-Polarized Quasi Yagi-Uda Antennas with End-Fire Radiation for Millimeter-Wave MIMO Terminals

from Electromagnetics Group

I. INTRODUCTION

THE rapid growth of high-quality data streaming and the growing number of wireless devices reflect the increasing global demands on mobile communication in the near future. Currently, the 4G system provides high-capacity service for mobile multimedia content with a data-rate range extending from 100Mbps to 1Gbps. To meet these demands, the next-generation mobile-communication system (5G) has set a target speed rate of multiple Gbps with higher capacity and lower latency than today's wireless systems have [1]. As the bandwidth is directly proportional to the communication data rate, a quite promising solution is to shift the carrier frequency to the millimeter wave (mmW) regime [2].

In this paper, we propose an integrated design of dual-polarized quasi Yagi-Uda antennas using the cost-effective PCB process. We have co-designed horizontally and vertically polarized quasi-Yagi antennas for a single area with two separate ports. Moreover, for end-fire pattern diversity, we have properly configured the presented antennas with the corner design and lateral design so as to achieve the optimal pattern coverage of the MIMO system, as depicted in Fig. 1.

To strengthen the practicality of implementation, we have employed the PCB process, instead of LTCC, thus ensuring the low cost of manufacturing and packaging in SiP mass production for handheld devices. The

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GICE Honors

Prof. I-Hsiang Wang
2016 Outstanding Teaching Award of National Taiwan University

Prof. Tzong-Lin Wu
IEEE EMC Society Board of Directors (BoD)

Message from the Director

Tzong-Lin Wu

Professor & GICE Director

With the camellias blossom in the campus and the chilling wind hits you on your face, we know it's time to see off the departing old year and usher in the new one.
Setting new goals and challenges and continuing to strive for excellence has always been the most important part of GICE as before.
This issue we invite Prof. Yi-Cheng Lin from Electromagnetics group and Prof. Hen-Wai Tsao from communication and signal processing group to share their recent research. Enjoy the reading!
Lastly, may all of you have a prosperous, successful, peaceful and fruitful new year that is filled with full of happiness.

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presented antennas are notable for their broad bandwidth, high-gain beam scanning, dual-polarized MIMO capability, and decent port isolation. All these features are crucial requirements for 5G mmW systems.

Fig 1. Placement of the end-fire antennas in a mobile terminal with the corner and the lateral designs.

II. DESIGN AND IMPLEMENTATION FOR THE CORNER DESIGN

Fig. 2(a) demonstrates the configuration of the presented dual-polarized quasi Yagi-Uda antennas for the corner design. The proposed antenna consists of vertical-polarization (V-pol) and horizontal-polarization (H-pol) quasi Yagi-Uda antennas implemented on a 3-layer PCB structure with a total thickness of 1.93mm. The substrate is the Rogers RT/Duroid® 4003 with a dielectric constant εr=3.38. The antenna's total size is 12.2mm by 11mm.

A.Vertical-Polarization Quasi Yagi-Uda Antenna

Fig. 2(b) illustrates the cross-section view of the proposed vertical-polarization quasi Yagi-Uda antenna. Both the driver and two directors consist of vias, each measuring about a quarter wavelengths. We have employed the image theory to achieve the required operation frequency under a limited substrate thickness. This antenna features a corner-shaped reflector composed of via walls. The antenna input impedance is around 100Ω where the tapered micro strip line feed converts the impedance to a 50Ω port for connecting RF circuits or for probe test with 400μm-pitch GSG pads, as shown in Fig. 2(c).

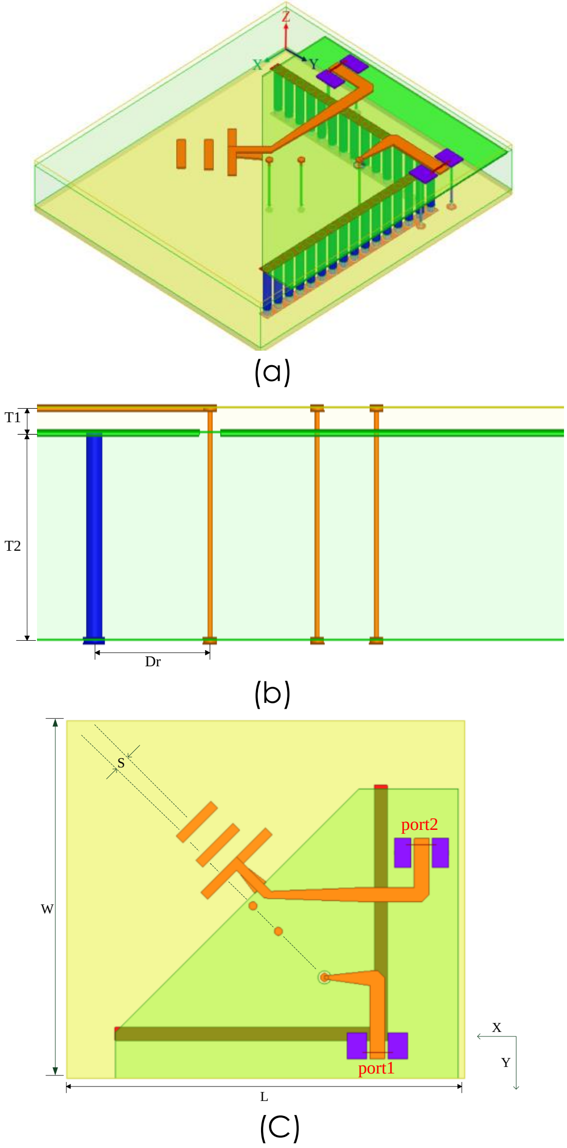

Fig 2. The dual-polarized quasi Yagi-Uda antenna for the corner design: (a) the perspective view, (b) the cross-section view, and (c) the top view.

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B. The Horizontal-Polarization Quasi Yagi-Uda Antenna

Similar to the classic quasi Yagi-Uda antenna, the proposed H-pol antenna consists of a truncated ground as the reflector, half-wavelength differential-fed metal arms as the driver, and two short metal strips as directors, as shown in Fig. 2(c). To avoid distorted radiation patterns, we have tapered the lower arm of the driver element to balance the current distribution between the two arms. The driver is nearly a half-wavelength long, corresponding to the center frequency of 36GHz.

III. PERFORMANCE AND VERIFICATION FOR PATTERN

In order to measure the gain patterns of the proposed dual-polarized antenna, we connected our antenna to an end-launch connector, as shown in Fig. 3. An end-launch connector, which clasps onto the top and bottom edges of the tested sample, serves as a transition between the printed transmission line of GSG pads and co-axial systems. However, a typical end-launch connector is 12mm wide, which is even larger than the antenna itself. Therefore, we designed a test kit with an extended micro strip line and a ground plane. Fig. 3 shows the resultant configuration of the modified corner design with connectors. Since the connector has a large piece of metal near the antenna, we extended the PCB panel with extra space between antennas and connectors to reduce the influence of the connector on radiation patterns.

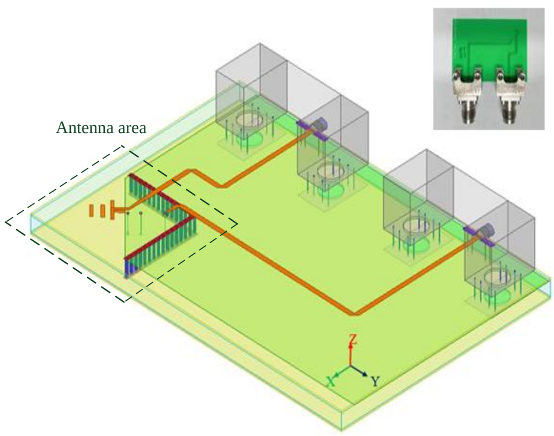

Fig 3. Test kit of the corner-design antenna with end-launch connectors to each port for pattern measurement.

Fig. 4 shows the simulated and measured results of the V-pol radiation patterns at 36 GHz. It can be observed that the maximum radiation was about θ=90° and φ=-45° while its front-to-back ratio was better than 12dB and the cross-polarization isolation was above 18.3dB. The peak realized gain was above 7dBi, as shown in Fig. 5, where the antenna efficiency was constantly above 90%. The peak gain slightly increased as the frequency increased.

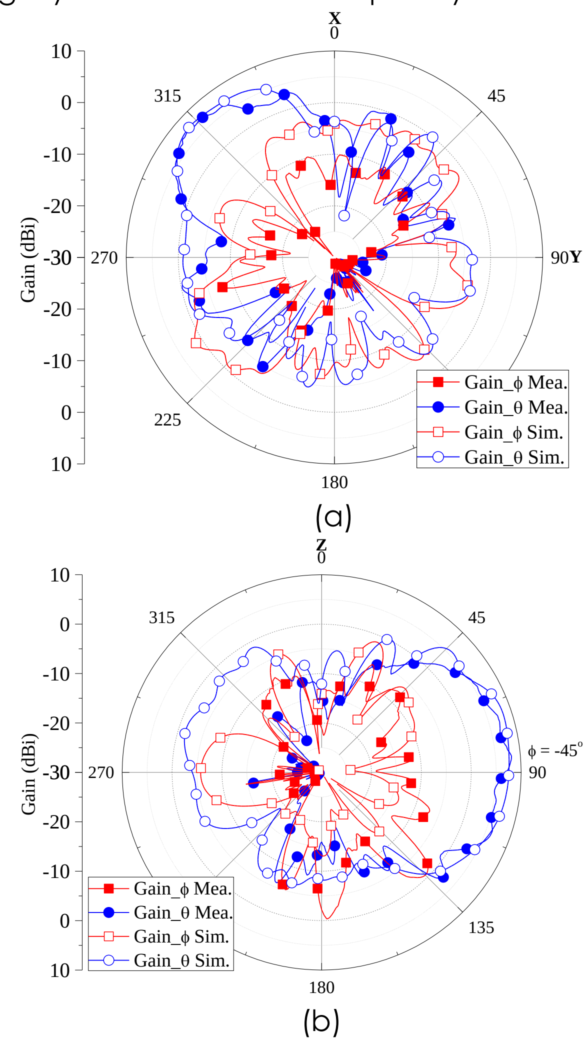

Fig 4. Radiation patterns of the corner-design V-pol antenna at 36 GHz with a connector: (a) the azimuth cut; (b) the elevation cut.

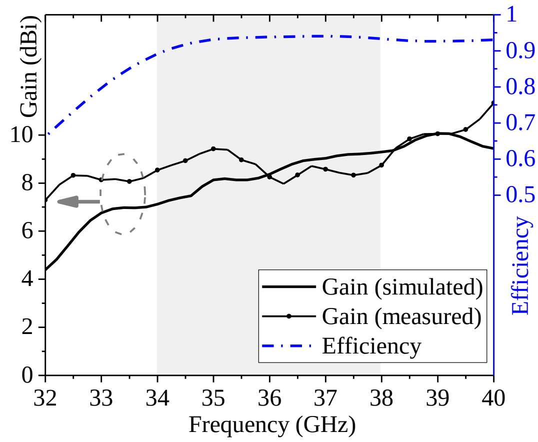

Fig 5. Gain and efficiency spectrum for the corner-design V-pol antenna.

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Technology

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IV. CONCLUSION

In this study, we have covered the design, implementation, and measurement of the proposed compact dual-polarized quasi Yagi-Uda antennas. The proposed design successfully integrates the H-pol and V-pol quasi-Yagi antennas into a single area, achieving polarization diversity and size reduction. We examined the proposed dual-polarized antennas on the basis of the PCB process in the mmW band, with an operating frequency measuring about 36GHz. We verified that the peak realized gain could achieve above 6.5dB for individual antenna elements.

ACKNOWLEDGMENT

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Design of a Software-Defined Radio Receiver for Two-Way Satellite Time and Frequency Transfer (TWSTFT) Applications

from Communication and Signal Processing Group

In cooperation with the Integrated System laboratory, GICE, Telecommunication Laboratories, Chunghwa Telecom Co., Ltd., the Bureau International des Poids et Mesures, and many national metrology institutes.

I. INTRODUCTION

The bureau international des poids et mesures (BIPM) generates Coordinated Universal Time (UTC) by weighting the timing of a number of atomic clocks that spread worldwide. This must rely on time transfer techniques to compare the clocks at different National Metrology Institutes (NMIs). Two-way satellite time and frequency transfer (TWSTFT) is a time transfer technique that has been used for several NMIs to synchronize their local realizations with UTC. In Taiwan, the Telecommunication Laboratories (TL), Chunghwa Telecom Co., Ltd. is in charge of realizing and maintaining the local realization of UTC, called UTC(TL). However, as atomic clocks become more and more stable, the stability of TWSTFT must also be improved. However, as shown in Fig. 2, the time-difference data has fluctuations with a period of one day, which are known as the diurnal effect, making it difficult to enhance this stability.

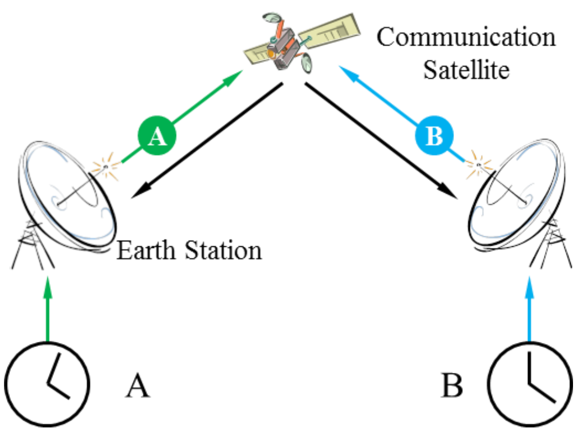

Fig. 1. Two clocks A and B are compared by using a TWSTFT system that comprises two earth stations and a communication satellite

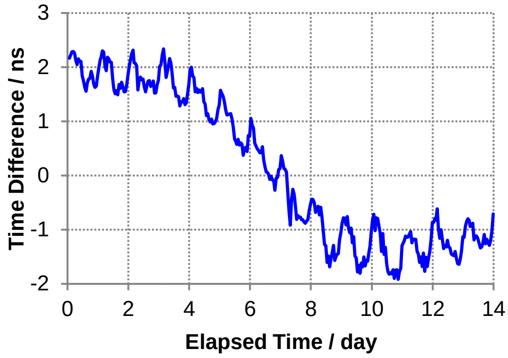

Fig. 2. The diurnal effect: the measurement fluctuates of about +- 0.5 ns with a period of one day.

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II. DESIGN OF A TWSTFT RECEIVER BASED ON SOFTWARE-DEFINED RADIO

In the TWSTFT receivers, conventional measurement algorithm usually employs two correlators and a delay-locked loop (DLL). Using the DLL, the dynamic behavior of the observed time of arrival (TOA) can contain steady-state and pull-in errors that make the measurement inaccurate. Also, the multipath error and multiple access interference (MAI) are difficult to mitigate due to that limitations of hardware resources. Therefore, a TWSTFT receiver that uses software-defined radio (SDR) technique is proposed [1-2]. The receiver system comprises an analog-to-digital conversion sampler at IF and a computer with a graphic processing unit (GPU) board. The SDR receiver realizes our custom-designed algorithm, including the multiple correlator and the open-loop synchronization scheme. In addition, a high-resolution correlator and the successive interference cancellation (SIC) respectively mitigate multipath effect and MAI using parallel computation provided by the GPU board [3].

III. THE SDR RECEIVERS WILL BE A PART OF UTC

Since 2014, TL has been cooperated with National Institute of Information and Communications Technology (NICT), Japan, and Korea Research Institute of Standards and Science (KRISS), South Korea, in operating the SDR receivers.

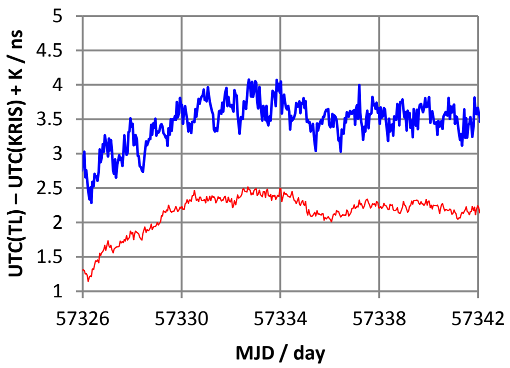

Fig. 3. The time-difference measurements by using conventional modem (blue line) and the SDR receivers (red line).

In Fig. 3, the measurement results between TL-KRISS show a clear suppression of the diurnal effect. The BIPM and the Consultative Committee for Time and Frequency (CCTF) working group on TWSTFT launched a project to install the SDR receivers in NMIs in Asia, Europe and the USA to generate UTC. As shown in Fig. 4, twelve NMIs, whose atomic clocks contribute a total weight of about 40% in UTC, have been operating the receiver. As a result, most of the TWSTFT results show an improvement in short-term stability, and some of them even exhibit complete disappearing of the diurnal effect.

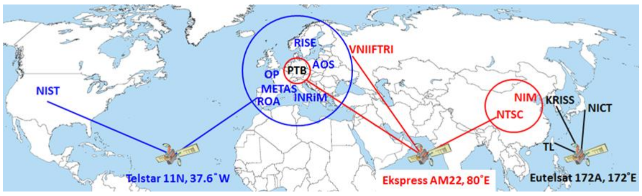

Fig. 4. The TWSTFT links and the participating NMIs that use the SDR receiver in February 2017. (source of the background: Google map)

IV. CONCLUSION

The TWSTFT system with proposed SDR receiver can effectively suppress the diurnal effect and improve the stability by a factor of two in the best case. The SDR receiver can more faithfully reflect the differences of atomic clocks among NMIs than the receivers currently used. For the BIPM, the accuracy of UTC can be improved if the data of the SDR receivers can be included in the UTC generation. For each NMI, the receiver will have less uncertainty in synchronizing its UTC(k) to UTC.

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Activities

The 2017 2nd Seminar of TEMIAC

The workshop in the area of array antennas, co-hosted by Prof. Hsi-Tseng Chou, National Taiwan University and Prof. Ding-Bing Lin, National Taiwan University of Science and Technology, was held in Barry Lam Hall room 101 on Monday, October 2. The objective was to deliver the knowledge about recent advance and future trends in array antennas to industries and students.

It was co-sponsored and co-organized by Taiwan Electromagnetic Industry-Academic Consortium and Educational Ally of RF Circuit Design in Mobile Communication supported by the Ministry of Education, in cooperation with High-Speed RF and mm-wave Technology Center, National Taiwan University, Graduate Institution of Communication Engineering, National Taiwan University, Oriental Institute of Technology Department of Communication Engineering, IEEE EMC Taipei Chapter, Institute for Information Industry, Industrial Technology Research Institute.

Many applications require radiation characteristics that may not be achievable by a single element. However, it may be possible that an aggregation of radiating elements in an electrical and geometrical arrangement (an array) will result in the desired radiation characteristics. Array antenna was first utilized in military field, such as Radar. Nowadays, it has been applied in various areas of communications including MIMO (Multiple Input Multiple Output), Massive MIMO, and so on. With the development in technologies like fifth-generation mobile network, internet of Thing (IoT) etc., the design considerations for the antennas become more diverse and complicated. Larger bandwidth, beam shaping, short range device to device communications, operation in wider range of frequencies etc. are some of the key requirements, and array antennas are expected to play an important role in achieving these requirements.

The workshop has invited several key experts and professors in the field including CEO Tsai Yao-Ming from Training Research Co., LTD, TRC , Prof. Paolo Nepa from University of Pisa, Pisa, Italy, Prof. Yu-Jiu Wang from National Chiao Tung University, Doctor. Guo li-ruey from WHA YU Industrial Co., Ltd., engineer Chen jian-Jia from National Instruments. The speakers shared experience and knowledge about their researches which provided a deeper understanding on recent developments and the future of array antenna to the attendees. Student attendees had the opportunity to learn the industrial aspects of technologies in need for industrial applications. These will help students to develop better skills and abilities, and we wish them to make ground-breaking contributions to the field of array antennas in their coming career.

Last but not least, we also provided an hour of forum for exchanging information on the progress of antennas, propagation, electromagnetic theory, and related fields. The mutual interaction among the participants was also one of the important objectives. The forum was chaired by Professor Hsi-Tseng Chou. Attendees used this hour to ask questions to the professors and experts on the stage. In addition to the speakers mentioned earlier, we also invited Prof. Tzong-Lin Wu, Chairman of Graduate Institute of Communication Engineering, National Taiwan University to take part in this forum. In spite of just an hour, everyone participated in the discussion enthusiastically. It is worth to mention that more than 210 participants attended this workshop, which indicates a growing interest in the field of array antennas.

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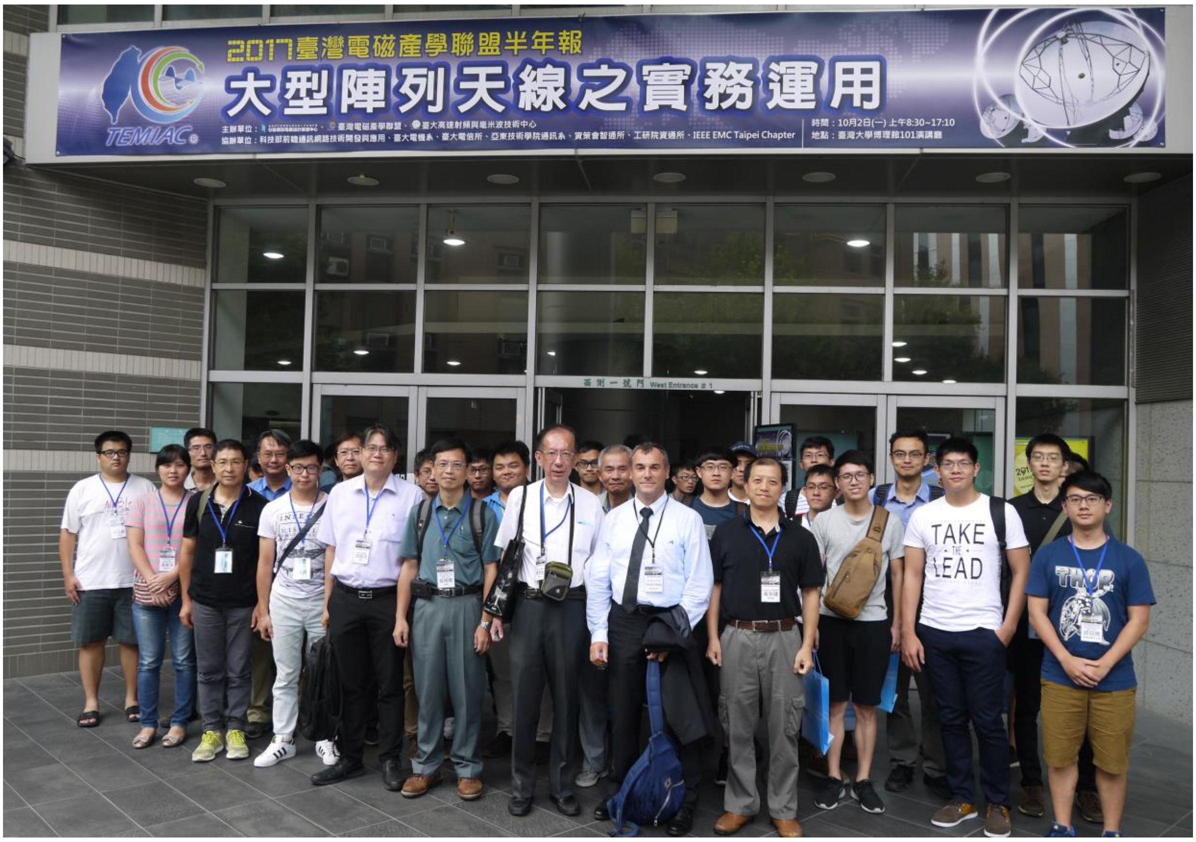

Group photo

Corner of student news

Article by Hung-Yi Chen, a Master Degree student in NTU GICE, chose to take part in a German internship program supported by MOST and DAAD in 2017 summer.

This article deals with the differences of day life and research style between NTU and my intern life in TUM, Germany. I learned a lot during these three months and this is the only opportunity in my lifetime. In the first part, I would briefly introduce the program. The second part is my research life in fortiss GmbH, a research institute associated with TUM. Then the final part is the different lifestyle between Taipei and München.

MOST-DAAD Summer Institute Programme selects 10 Taiwanese students in Master/PhD degree every year to start internship in German Universities/Institutes for 2-3 months. This program not only subsidizes transportation fee (flights and trains) but also provides enough stipends for participants' daily life. Given that this program accepts non-German applicants, which is welcome for NTU GICE students with qualified TOEFL/IELTS grade. Once applicants are admitted by the program, DAAD will arrange a one-week orientation in Bonn for research students from Taiwan and Korea. During this week, all participants have enough time to get acquainted with other students from different background, have a better understanding to DAAD and German culture. In the last day of the training program, we visit Mt. Drachenfels in Bonn and gaze afar the Rhein from its top.

The overlook of Rhein river

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Corner of student news

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The group photo on Mt. Drachenfels

I started my internship in fortiss GmbH, a non-profit research institute associated with TUM and focusing on developing verification tools for software. After signing many confidential documents, I was assigned to a project concentrating on the robustness of the autonomous driving system. Provided that each full-time worker has 30-day-leave-without-reason each year. In other words, German advisors and mentors even keep their business e-mail non-used during their leave, which makes interns hard to contact them. Thus, the first lesson I learned is to work and solve problems more independently. Moreover, the German laboratory is composed of PhD/Postdoc mostly. Master degree students in TUM are only required to do laboratory research for one semester, which is a great difference between NTU and TUM. Finally, I was so glad that my English listening/presenting skill has improved because I worked on the same project with colleagues around the globe. Last but not least, it is unwelcome to work overtime so my colleagues usually work efficiently and leave office before 16:30 to take sunbathing and beers in the English Garden. One day, I finished my work early and invited my Korean colleagues to savor the best cheese cake in München. After that, we made Korean Sushi, Kimbap, together in my kitchen and have a nice dinner.

Making Kimbap as dinner.

Although the commodity price of München is very high (highest in Germany), the price of raw materials could be lower than Taipei. For instance, it costs 8-12 EUs for western and 6-10 EUs for Chinese/Janpanese meal. Therefore, cooking by oneself in Germany not only saves money but also improves one's culinary skill. Secondly, 99% supermarkets close before 20:00 in Bayern. Two features above are inconvenient because there are many cheap restaurants and 24-hour convenient stores in Taiwan. Last but not least, joining this program broadens my scope of view. Since Germany has convenient transportation system in both trains and buses. It is a good opportunity for participants to visit many cities/towns in Germany when participants have free time during internship.

How fortunate I was to take part in such a great program. I would like to thank my family, advisors, colleagues and everyone who helped me during these years. I would not be the person that I am today without all your assistance.

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