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In this issue

Technology Developed in GICE

Flexible Design for 5G NR Multicast and Broadcast

from Data Science and Smart Networking Group

INTRODUCTION

To deal with the overwhelming traffic through limited radio resources, delivering a single data packet to multiple users through a common channel enhances the efficiency of radio resource usage. As such, the third generation partnership project (3GPP) has introduced multimedia broadcast multicast service (MBMS) in long-term evolution (LTE).

However, commercial deployments of LTE MBMS can be barely found. One of the reasons is that LTE MBMS does not support feedbacks from user equipment (UE); hence, a base station (BS) is forced to transmit data with the most robust modulation and coding scheme (MCS), which greatly harms the efficiency. Another reason for the mere commercial deployments is the lack of temporal and spatial flexibility. A single frequency network (SFN) consists of one or multiple BSs transmitting the same data packets on the same radio resources. In LTE MBMS, the SFN areas are barely adjusted once they are determined. In this case, when a group of UEs flock to another area, the efficiency decreases due to the vain transmission of the BSs without any UE. To overcome the problem, we propose a configurable and flexible SFN system and design an SFN area partition algorithm to optimize the performance in such a system.

SYSTEM ARCHITECTURE

As shown in Fig. 1, a legacy MBMS system is composed of a broadcast multicast service center (BM-SC), an MBMS gateway (MBMS-GW), a multi-cell coordination entity (MCE), some BSs, and some UEs. A BM-SC is responsible for the reception of service content from the content provider, and an MBMS-GW is in charge of the data delivery to their correct destinations. As for MCE, it takes the role to coordinate BSs in SFN areas, such as scheduling and synchronization. At the edge of the network lie the BSs, which transmit the MBMS service data to UEs.

The collection procedure of channel quality information is depicted in Fig. 2. The MCE periodically commands for

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GICE Honors

Prof. Tzong-Lin Wu

2020 The 27th Teco Award

Prof. Hsuan-Jung Su

2020 CIEE Outstanding Electrical Engineering Professor Award

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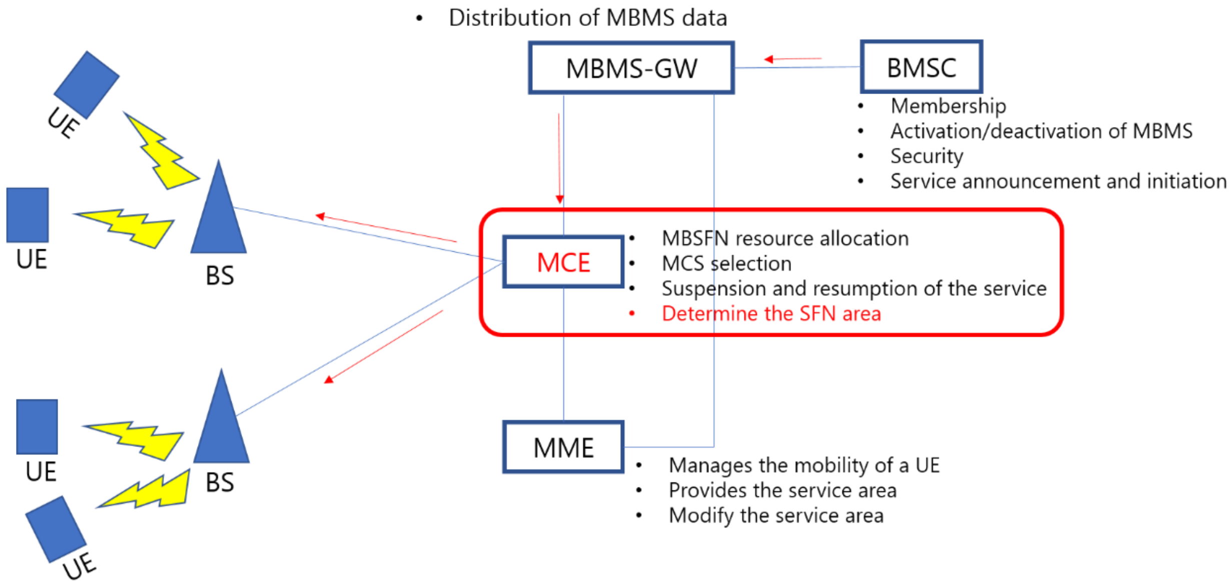

Fig. 1 The system architecture for LTE MBMS

the feedback of channel quality. During the configuration modification, the MCE reconfigures the mapping relationship between a BS and its SFN area, That is, the topology is partitioned, and we will introduce the detailed partition algorithm in the next section.

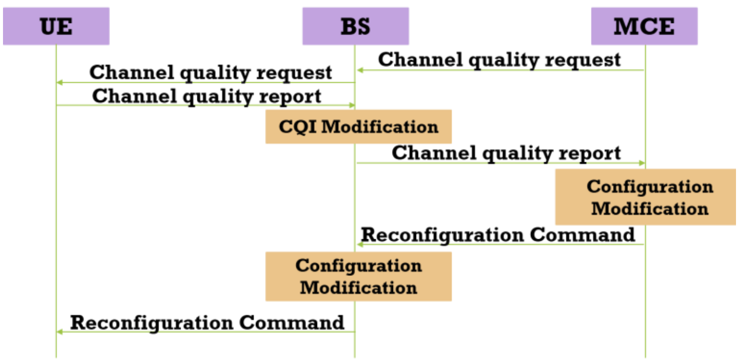

Fig. 2 The proposed signaling flowchart to collect UEs' channel qualities

PARTITION ALGORITHM

We propose a graph-based greedy partitioning algorithm (GGPA) to efficiently find a suboptimal solution for a given topology. In GGPA, there are a decomposition stage and a merging stage.

The decomposition procedure is shown in Fig.3. Initially, all of the cells are scheduled in a group, which is called main group in the following parts of the article. We define an exclusion value of a cell as the difference between the value before and after the cell is excluded from the main group. The algorithm iterates finding the cell with the greatest exclusion value and removing the cell from the main group until there is no cell with positive exclusion value in the main group. Then, the partitioning algorithm proceeds to the merging stage.

In the merging stage, as shown in Fig.4, we regard the excluded cells in the decomposition stage as individual groups. We treat the merging process as a graph. The vertices in the graph represent the groups in the topology, while the weights of edges stand for the merging value. Here, we define the merging value between two groups as the value that is yielded by merging the groups. Our algorithm

Message from the Director

Hsuan-Jung Su

Professor & GICE Director

Happy Chinese New Year! Hope everybody can get together with family and love ones and have good plans for the New Year holiday. We have great news to share. Prof. Tzong-Lin Wu received the 2020 TECO Award which recognizes leaders in various disciplines. Prof. Hsuan-Jung Su received the 2020 CIEE Outstanding Electrical Engineering Professor Award. Congratulations!

In this issue, we continue to highlight the excellent researches on 5G and beyond done by our professors. Prof. Hung-Yu Wei shares his research on Flexible Design for 5G NR Multicast and Broadcast. Prof. Shih-Yuan Chen shares his research on probe- and phase-compensated three-dimensional microwave imaging. In addition, we have had many great activities in the past quarter. The GICE Students Association briefs on the student event of a laser tag game. GICE Prof. His-Tseng Chou organized the Workshop on 5G RF Technology and Verification which was opened by GICE Prof. Ruey-Beei Wu's speech. GICE professors also hosted IEEE GLOBECOM, a flagship conference of IEEE Communications Society (ComSoc), in December 2020, which will be reported in the next issue of the GICE Newsletter. Please stay tuned.

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iterates finding the pair of groups with the greatest merging value and merge them into a new larger group until there is no positive merging value in the graph.

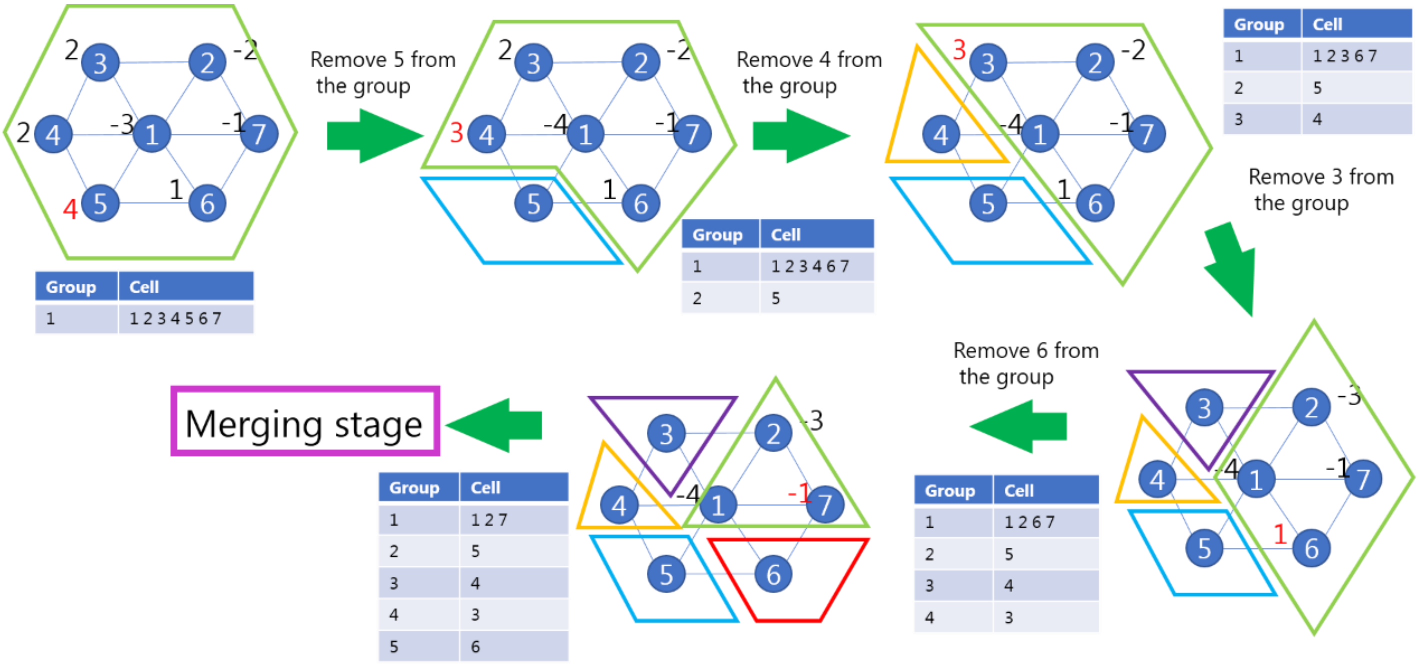


Fig. 3 The iterative procedure in the decomposition stage of GGPA

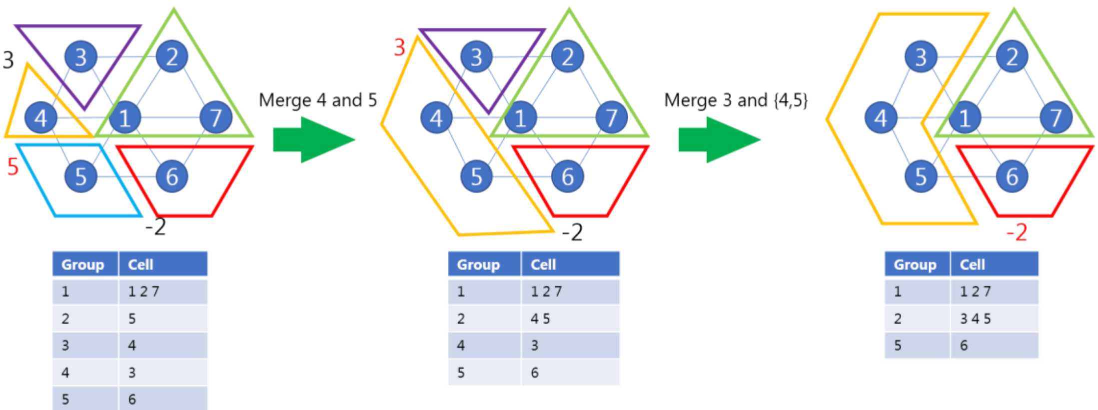
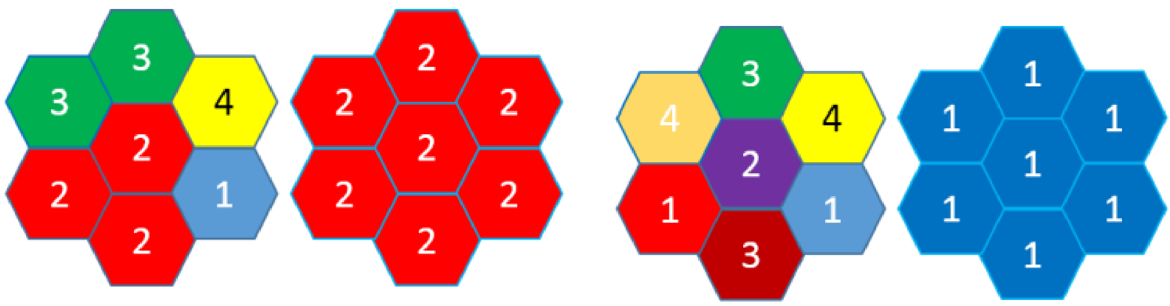


Fig. 4 The iterative procedure in the merging stage of GGPA

SIMULATION RESULTS

As shown in Fig. EE, we compare our designed GGPA with exhaustive search, all SFN (ASFN), all PTM (APTM), and LTE-based All SFN (LASFN). In Fig. 5(a), exhaustive search ensures the optimal solution of the partition problem at the cost of higher time complexity. In ASFN method, all of the cells are put into a single group, whereas in APTM method, different cells are put into all different groups. As for LASFN, all of the cells are put into a single group as in LSFN. Nevertheless, since LTE MBMS does not support feedback, the cells in the group have to assume the lowest MVS level to ensure the reception reliability.



(a) Eshaustive Search (b) All SFN Method (c) All PTM Method (d) LTE-based All SFN

Fig. 5 An example for the partition results yielded by the compared methods

In our work, we take sum log rate for the utility function. The results are shown in Fig.6. Since the exhaustive search method always yields the optimal solution, we normalize the utility yield by each method with the optimal utility. For 7-BS scenario, according to Fig.6(a) to Fig.6(d), the proposed GGPA outperforms ASFN, APTM, and

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ALSFN. Since the time complexity is unaffordable for exhaustive search for 19-BS topology, we use the utility yielded by GGPA as the standard for the normalization. As shown in Fig.6(e) to Fig.6(h), GGPA still outperforms the other 3 methods.

To evaluate the time complexity, we compare GGPA with exhaustive search. The execution time of exhaustive search grows exponentially with the number of cells; meanwhile, the execution time of GGPA takes linear growth. That is, for a small topology, exhaustive search could be a good method, but GGPA takes less computational cost for larger topologies.

CONCLUSIONS

We pointed out the deficiencies of LTE MBMS and then proposed a framework for dynamic SFN area deployments in NR MBMS. Then, we proposed GGPA in addition to the exhaustive search method. The simulation results show that GGPA adapts under different scenarios, outperforms the other intuitive methods for most of the time, and consumes less execution time than the exhaustive search. Therefore, GGPA is a suitable and efficient algorithm for configuring the SFN area in the future NR MBMS network.

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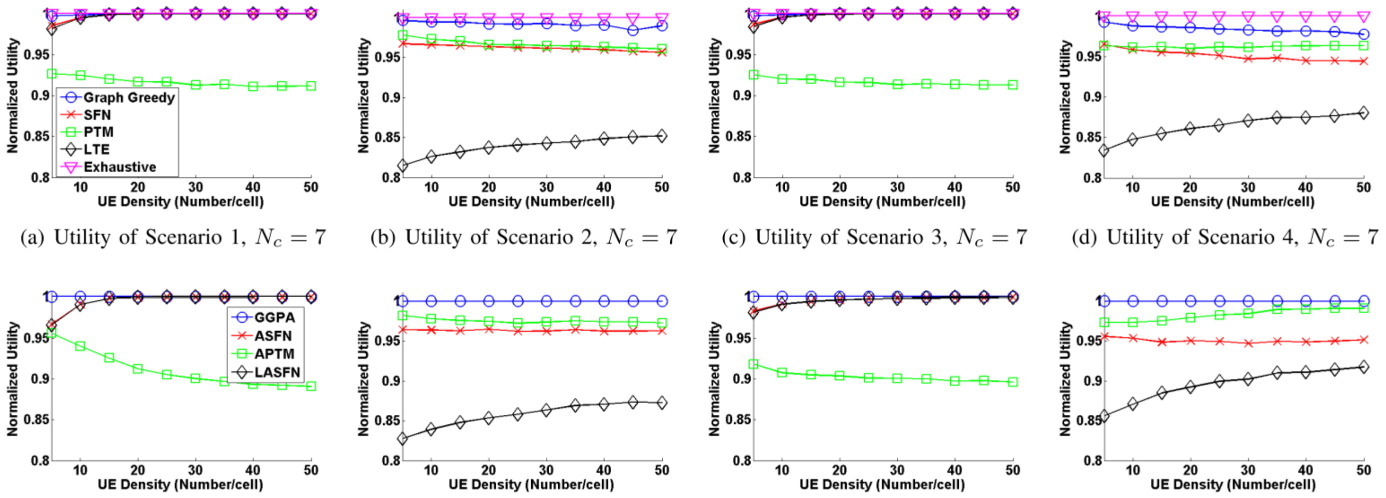

(a) Utility of Scenario 1, $N_c = 7$ (b) Utility of Scenario 2, $N_c = 7$ (c) Utility of Scenario 3, $N_c = 7$ (d) Utility of Scenario 4, $N_c = 7$

(e) Utility of Scenario 1, $N_c = 19$ (f) Utility of Scenario 2, $N_c = 19$ (g) Utility of Scenario 3, $N_c = 19$ (h) Utility of Scenario 4, $N_c = 19$

Fig. 6 The simulation results. The upper row shows the utility under 7-BS scenario and the lower row shows the utility under 19-BS scenario.

Dual-Probe Probe- and Phase-Compensated Three-Dimensional Microwave Imaging Using Only Reflection Coefficients

from Electromagnetics Group

In the current issue of the newsletter, a probe- and phase-compensated three-dimensional microwave imaging algorithm based on the dual-probe scanning setup (Fig. 1(a)) with the need of only the reflection coefficients is introduced. The proposed imaging method and the associated results presented here have been published in our previous paper [1]. This dual-probe imaging *method is extended from the one based on single-probe scanning setup (Fig. 1(b)), in which an auxiliary equation must be used to ensure a reasonable numerical stability [2]. By comparing the images reconstructed by the proposed dual-probe algorithm using respectively* only the reflection coefficients (Fig. 2), only the transmission coefficients (Fig. 3), and both reflection and transmission coefficients (Fig. 4), one can see that the numerical stability of the dual-probe imaging algorithm is dominated by the reflection coefficients and that the contributions of transmission coefficients to numerical stability as well as the image quality are negligible. Moreover, the condition number of the proposed dual-probe reflection-coefficient-only imaging algorithm is equal to that of the single-probe algorithm exploiting the auxiliary equation. To verify this, the images reconstructed using the two algorithms are shown in Figs. 5(a) and (b), respectively. All parameters of the two scanning setups are kept the same as those adopted in Figs. 2-4 except for the use of only one probe antenna in the scanning setup (Fig. 1(b)). For conciseness, only the images reconstructed with FBW = 100% are presented here. As expected, the image quality is about the same in Figs. 5(a) and (b). This also implies that the lossless assumption imposed by the auxiliary equation can be discarded in the proposed dual-probe algorithm. The proposed algorithm is feasible for imaging lossy dielectric targets at no extra computational cost.

The ability of the proposed dual-probe probe- and phase-compensated reflection-coefficient-only algorithm to deal with targets made of lossy dielectric and to retrieve both the real and imaginary parts of its complex relative permittivity is demonstrated here. Again, the aforementioned exemplary case with FBW = 100% is considered but with the dielectric loss tangent of the target reset to 0.5, i.e., the imaginary part of the relative permittivity being equal to -1. The images, or the distributions of the real and imaginary

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parts of the relative permittivity, reconstructed using the proposed dual-probe reflection-coefficient-only algorithm are shown in Figs. 6(a) and (b), respectively. One can see that the image quality of the real part of the relative permittivity is about the same as its lossless counterpart, i.e., Fig. 5(a). While the imaginary part of the relative permittivity of the target can still be predicted with reasonable accuracy, the image quality of the imaginary part is not as good, especially the artifacts on z = 57, 63, and 69 mm planes. This could be attributed to the simplified ray model used in the phase compensation method. Nonetheless, the proposed dual-probe reflection-coefficient-only probe- and phase-compensated imaging algorithm, verified by the above results, is proved applicable to the imaging of target made of lossy dielectric without sacrificing image quality and computational efficiency.

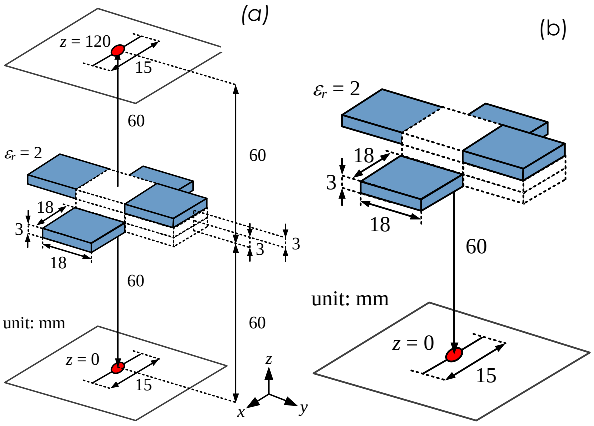

Fig. 1. (a) Dual-probe and (b) single-probe scanning setups with two orthogonal pairs of identical dielectric cuboids (dielectric constant of 2, lossless) as target.

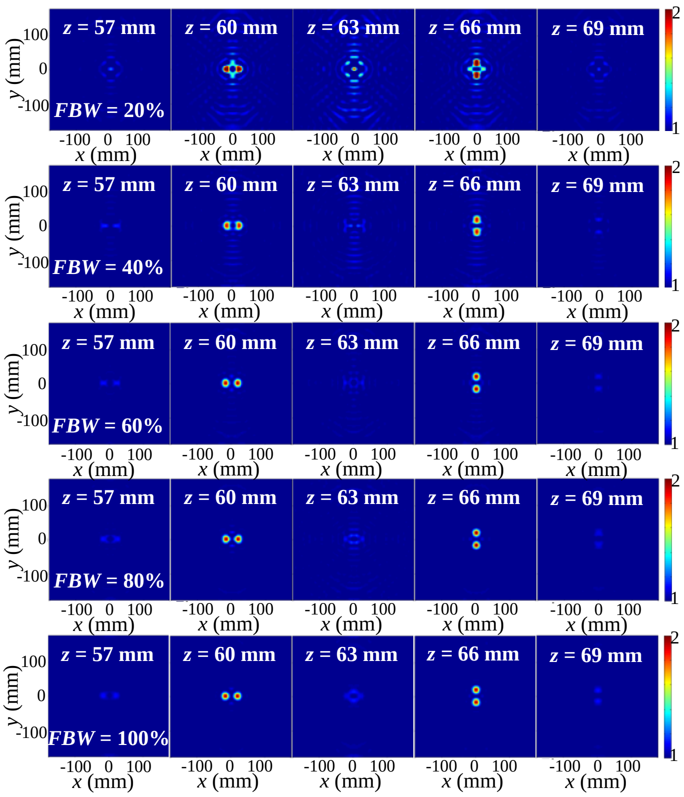

Fig. 2. Images reconstructed by the proposed dual-probe reflection-coefficient-only algorithm for various FBWs.

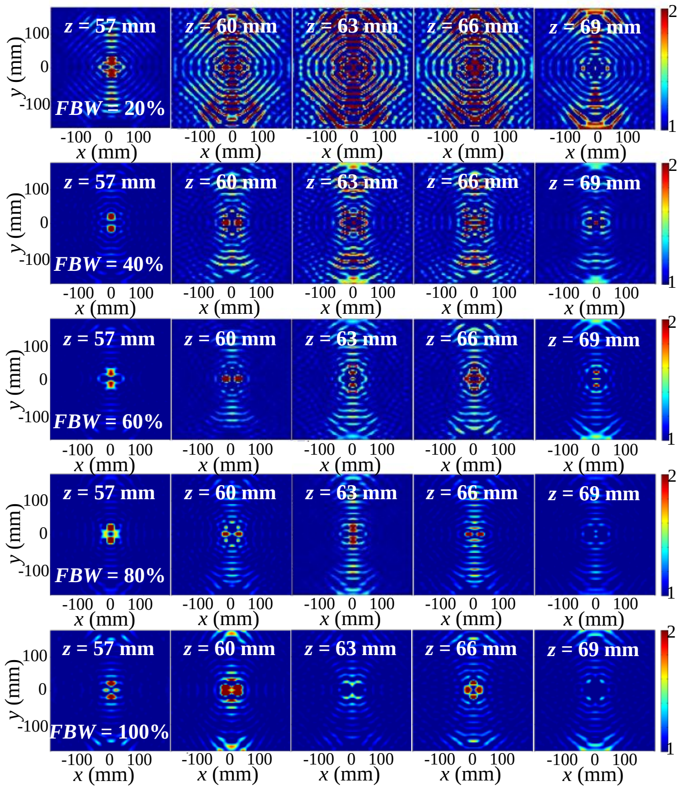

Fig. 3. Images reconstructed by the dual-probe transmission-coefficient-only algorithm for various FBWs.

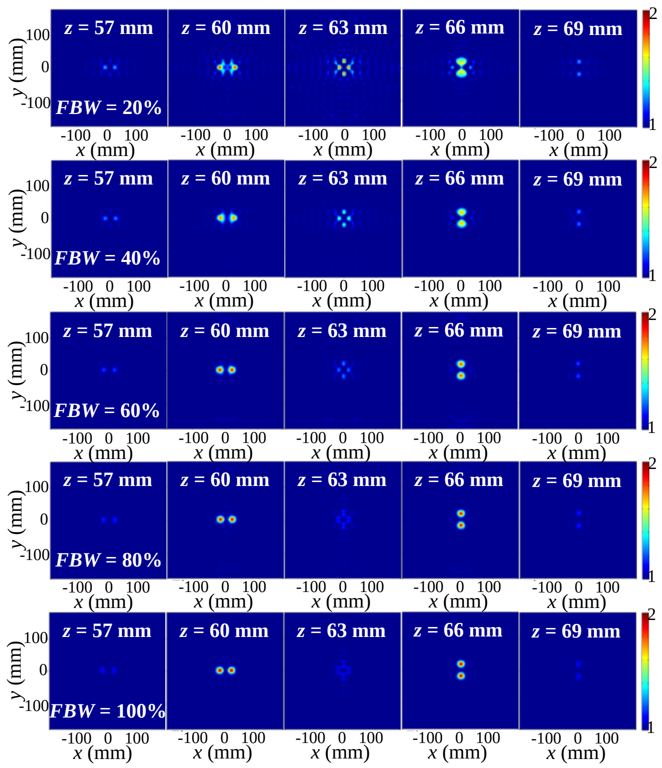

Fig. 4. Images reconstructed by the dual-probe algorithm exploiting both reflection and transmission coefficients for various

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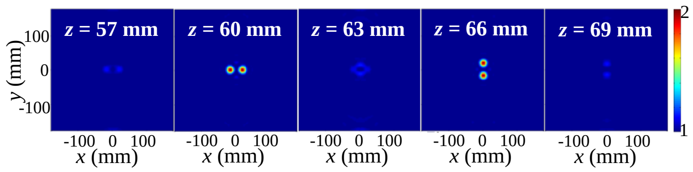
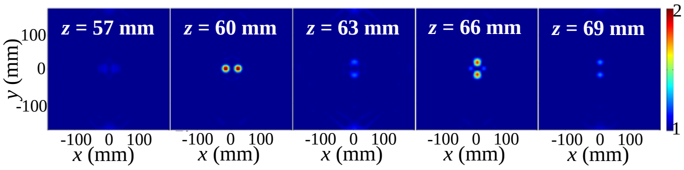
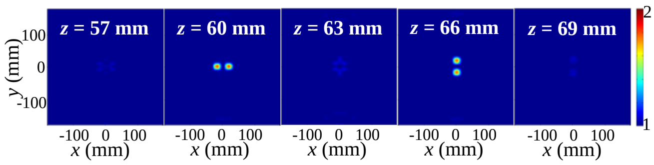


(a)

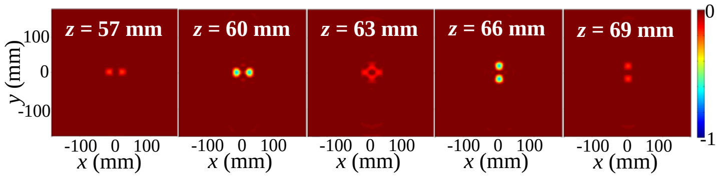


(b)

Fig. 5. Images reconstructed by (a) the proposed dual-probe reflection-only algorithm and (b) the single-probe algorithm with auxiliary equation.



(a)



(b)

Fig. 6. Images reconstructed by the proposed dual-probe reflection-only algorithm: (a) real and (b) imaginary parts of the relative permittivity.

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[1] C.-H. Tsai, J. Chang, L.-Y. Ou Yang, and S.-Y. Chen, "Dual-Probe Probe- and Phase-Compensated Reflection-Coefficient-Only Three-Dimensional Microwave Holographic Imaging," IEEE Trans. Antennas Propag., vol. 67, no. 3, pp. 1884-1897, Mar. 2019.

[2] C.-H. Tsai, J. Chang, L.-Y. Ou Yang, and S.-Y. Chen, "3-D Microwave Holographic Imaging With Probe and Phase Compensations," IEEE Trans. Antennas Propag., vol. 66, no. 1, pp. 368-380, Jan. 2018.

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The 2020 1st Semiannual Report of Taiwan Electromagnetic Industry-Academia Consortium: Microwave power amplifier Technical Development and Trends Symposium

On Sept. 25, 2020, a full-day workshop on "5G RF Technology and Verification" was held at National Taiwan University, Taipei, Taiwan. This workshop was organized by Taiwan Electromagnetic Industry-Academic Consortium (TEMIAC), 5G RF Technology Industry-Academic Consortium and IEEE EMC Taipei Chapter. It was also supported by the Talent Cultivation Program 5G Mobile Broadband Technologies – 5G Antenna and Radio Frequency Technology Alliance Center and the Project of Advanced Technology Developments for the Applications in Massive MIMO and Smart Antennas in Next Generation of Mobile Communications.

The workshop was hosted by Professor Ding-Bing Lin and Professor His-Tseng Chou for the morning and afternoon sessions, respectively. At the opening, Professor Ruey-Beei Wu, Chairman of TEMIAC and Professor Hsing-Yi Chen, Chairman of 5G RF Technology Industry-Academic Consortium welcomed the attendees to the workshop. More than 150 persons attended the workshop, including students, engineers, and researchers from industry, academia, and government.

Fig. 1-1. Professor Ruey-Beei Wu, Chairman of TEMIAC, gave a welcome speech to the attendees.

In the workshop, five 50-minute presentations were delivered, listed as follows:

1. 5G mm-Wave technology development and application trend, by Alex Chou, Chief Technology Officer of Auden Technology Company;
2. 5G mm-Wave antenna design and analysis accelerated by applying Python and electromagnetic solvers, by Mingchih Lin, Principle Application Manager of Ansys Taiwan;
3. mm-Wave AiP/AiM technology and applications, by Hsi-Tseng Chou, Professor of National Taiwan University;
4. Globe 5G industry developing trend after COVID-19, by Jeng-Rern Yang, Professor of Yuan Ze University;

Fig. 1-2. Professor Hsing-Yi Chen, Chairman of 5G RF Technology Industry-Academic Consortium, welcomed the attendees to the workshop.

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Activity

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5. 5G RF measurements and applications, Feiyu Chen, Application Manager of Rohde & Schwarz Taiwan Ltd.

They delivered broadly from the business trend, technology development, simulation and measurement techniques to many demonstrated cases of the 5G technology and verification. Through the discussing on current situation and future prospects, they concluded that the mm-Wave technology appears to be everywhere in our daily life and Taiwan shall hold the great opportunity.

Fig. 2-1. Dr. Alex Chou, Chief Technology Officer of Auden Technology Company, delivered a talk on *5G mm-Wave technology development and application trend*.

Fig. 2-2. Principle Application Manager Mingchih Lin of Ansys Taiwan delivered a talk on *5G mm-Wave antenna design and analysis accelerated by applying Python and electromagnetic solvers.* He discussed with Professor Ruey-Beei Wu and Professor Ding-Bing Lin.

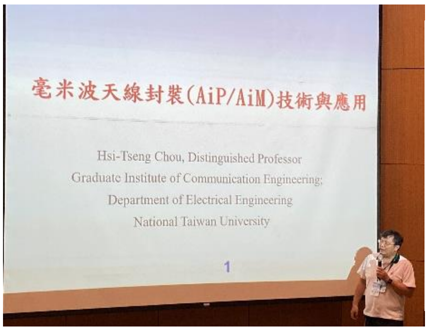

Fig. 2-3. Professor Hsi-Tseng Chou from National Taiwan University delivered a talk on mm-Wave AiP/AiM technology and applications.

Fig. 2-4. Professor Jeng-Rern Yang from Yuan Ze University delivered a talk on *Globe 5G industry developing trend after COVID-19*.

Fig. 2-5. Dr. Feiyu Chen, Application Manager of Rohde & Schwarz Taiwan Ltd., delivered a talk on 5G RF measurements and applications.

Fig. 3. Attendees talked to representatives of Auden Technology Company around the recruiting booth area.

NTU GICE Students Association - Student Event- Laser Tag Game

People need leisure time. Nevertheless, nowadays most graduate students tend to spend most of their free time surfing the internet, playing video games, watching Netflix or YouTube, tasks that physical activities are needless. Moreover, the epidemic of COVID-19 only worsens the situation. As one of the responsibilities of Professor Su, the Director of GICE is to ensure both physical and mental health of GICE students. Under his guidance, the GICE office and Students Association, as a result, conducted a "Laser tag game" for our students.

Laser tag game as it is being played for more than 40 years in Europe and America, which is a shooting game where players can shoot their opponents with a laser gun, individually or in teams, for scoring points or reaching certain goals. During the game, each player would have to wear a vest with several sensors and hold a laser gun. The entire process is extremely safe and gives no pain while other games like paintball does. Hence, everybody can join. There are in total six different games. Three individual games and three

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Activity

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group games. For instance, in "Deathmatch" each player of each team starts with 10 lives and the first team to lose all of their lives loses the game. In the game "Vampire", only few of players are assigned as vampires, and all the others are simply humans. Vampires never die, but a human will become a vampire after 10 shots. Human must fight to survive 5 minutes. If there are still some humans remaining after the game, humans win. Otherwise, you will let the vampires rule the world. In a futuristic maze walking in the shadows, surrounded by a mystical soundtrack, students would need all their skills to fulfill the missions.

Fig1. Students discuss their strategies.

Professor Su has also like students to know and communicate with each other during the game time, and that's the reason why "Laser tag game" is best suited for us. Every combat should be played with well-designed strategies. GICE students are categorized as different teams in the waiting lounge, and each member in each team intensively exchanges their observations, assumptions, and strategies. In my personal experience, in the game "VIP", a pal from India noticed that there was a covert space after the obsolete oilcans, where he thought the opponents would have never found. As the chosen VIP, by just simply staying in the region as planned in advance, we won the game easily by a landslide with all lives remaining. Taiwanese students as well as the exchange students from Italy, India, and the Philippines all enjoy the game. The game zone is ingeniously designed, the guns are really precise and sensitive, and the foods and drinks prepared are tasty as well. As the President of GICE's Students Association, I believe all attendants are satisfied.

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