The Finding of the Defects of an 6G Array Antenna Using Deep Learning Programs

Jinwoo Bae
Dept. of Info. & Telecomm. Eng.
Incheon National University
Incheon, Korea
wlsdn0120@inu.ac.kr

Sanghyun Yun
Dept. of Info. & Telecomm. Eng.
Incheon National University
Incheon, Korea
zzxx121512@inu.ac.kr

Woogon Kim
Dept. of Info. & Telecomm. Eng.
Incheon National University
Incheon, Korea
wgon1002@inu.ac.kr

Jaewon Koh
Dept. of Info. & Telecomm. Eng.
Incheon National University
Incheon, Korea
rhwodnjs91@inu.ac.kr

Hongsik Park
Dept. of Info. & Telecomm. Eng.
Incheon National University
Incheon, Korea
p0306ok@inu.ac.kr

Sungtek Kahng
Dept. of Info. & Telecomm. Eng.
Incheon National University
Incheon, Korea
s-kahng@inu.ac.kr

***Abstract*—This paper talks about a measure to hinder people from wasting resources of developing the wireless communication system by applying deep learning approaches. As the array antenna is essential but costly to the 6G mobile communication device, no single flaw is not allowed in its manufacturing as well as design, which leads them to checking a flaw or some in its geometry. A measure is taken to comb through the pixels of the array antenna and will tell you attributes of the physical error interpreted by the deep learning algorithms. The electromagnetic characteristics will entail the information of the classes of the defects. An 8-by-8 array working for 28 GHz is taken an instance of and the corresponding far-field patterns will be presented with technical comments.**

Keywords—Deep Learning Methods, 6G Mobile Communication, Antenna, Electromagnetics, Geometry

I. INTRODUCTION

Chat GPT is sweeping the whole world by attracting people from all walks of life. They are enchanted with a belief that AI can give limitless convenience to the daily lives and projects of a country. Business men are assisted by Chat GPT in tracking an answer for a puzzling question and making a report for a meeting where they are slated to answer that question[1]. Teachers who tried to keep students from indulging in counting on that product of AI for home-assignments are changing their attitudes to encourage the youngsters to solve a problem by referring to that assistant. Similar practices are being seen to classes on college campus.

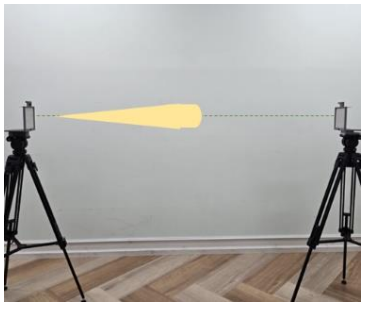
Not only doing such academic tasks which are destined to reach old solutions but also the areas where creativity is highly expected are being filled with outputs of using the product. Music for TV commercials is made and even new pieces of classical music-style melody are written and arranged. Money making is made possible by producing and selling art works like AI-empowered paintings and music works in the on-line and of-line markets and is being entered into scamming the innocent to invest or wire a huge amount of dollars to the wrong hands as in Deep Fake fraud[2]. Not sure whether AI has ethics on its mind or not, it plays that function as programmed, not knowing what moral or criminal consequences will occur. This has been driving researchers and the police to come up with AI programs to check that an advertisement is a fake. Their catch-phrase is good AI against bad AI. White hackers are deployed to bust the hackers. It goes without saying that AI is introduced with positive points like usefulness in the field of security and safety. Surveillance cameras are facilitated on the utility poles of corners of a town and collect pictures transferred to the data analysis center the police watch the scene. Images are processed and refined so that they are understood to the watchers. This is extended to monitoring the conditions in and out and control the driverless car whose area is handled known as safety on the road. Computer vision modules mounted on the front or roof of the car take pictures of head-on space and surroundings of the autonomous car and enable the MCU inside the car to detect an object or some and slow down or change the lane[3]. An increasing number of trades and areas have seen their walls torn down for crossover as AI is pushing the envelope.

The communication community has opened the door to AI[4]. Channel estimation, resource allocation, selecting paths of heterogeneous networks, etc. are solved by setting the initial values for the core parameters and adjusting them to get adaptivity and better results. Most of the problems are confined to the area of software. This paper challenges for a hardware problem in the communication system. The array antenna which plays a vital role in broadband mobile communication is the subject now. Especially, a defect or some of the antenna will be recognized and identified by the AI program. A very variety of geometrically faulty array antennas are input and they are distinguished to classes. Aimed to be operated at 28 GHz, an 8 times 8 array is set as the reference. Different kinds of antenna are labeled with the number of the defects. Their far-field patterns are presented.

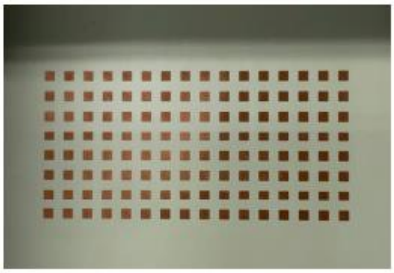
II. EXPECTED FUNCTION AND ERROR CAUSING CASES

A. Expected function of the antenna

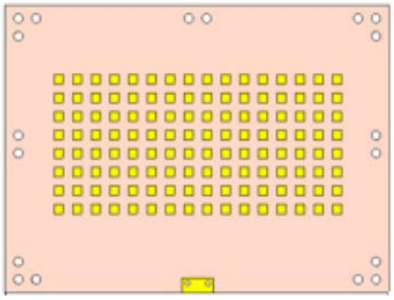
An antenna is a must-secure thing for wireless communication. That the caller holding the handheld phone talks to the receiver is expressed as the transmitter and receiver forming the wireless link with the help of antennas[4,5].



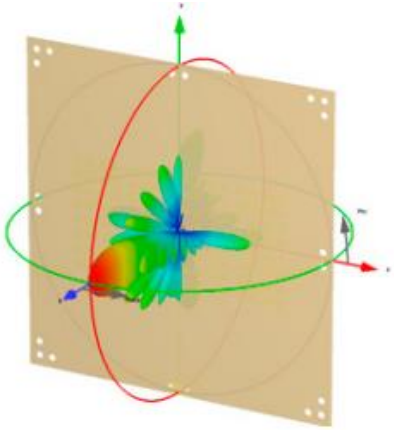
(a)



(b)



(c)



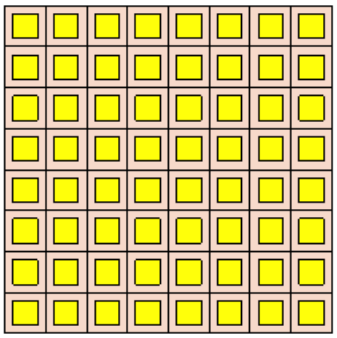
(d)

Fig. 1. Antennas for a wireless link (a)RF power sent from the TX antenna to the receiver (b)Antenna in reality (c)Antenna in the CAD program (d)Radiated wave pattern of the array antenna

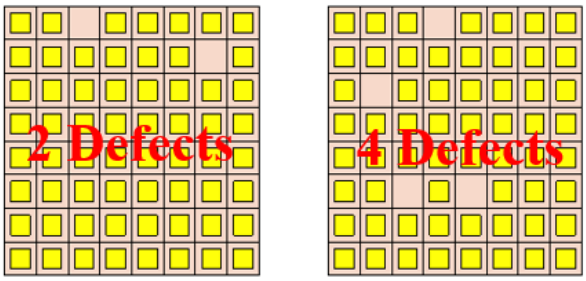
Figure 1(a) has the two blocks in the communication link which are the transmitter (TX) and the receiver (RX). Both the sides have antennas that generate an RF signal and send or catch it. When trying to accomplish wireless communication in the framework of broadband data transmission such as 5G and 6G, the frequency is so high that the signal cannot avoid becoming weaker by the distance from the TX to the RX, which leads to adopting array antennas. These are shown as in Figures 1(b) and (c). The hardware as in Figure 1(b) is realized by printing metal rectangular patches as the elements on a dielectric substrate whose shapes and sizes are determined in the CAD program as the software on the basis of electromagnetic calculating capability. It evaluates the far-field pattern or the beam pattern of the array as in Figure 1(d) used as seeing if the antenna works soundly or not.

B. Errors in the geometry of the antenna

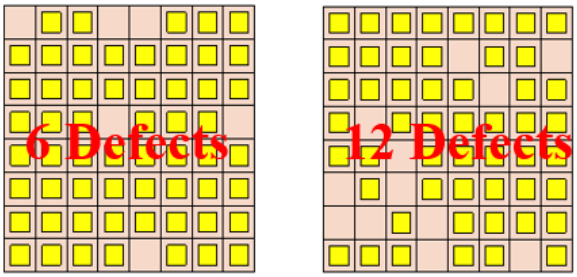
Chances are the antenna being manufactured with flaws in the shapes of elements or the entire antenna or sizes or regularity or material constant. For the sake of convenience, the error that will the most likely occur is equivalent to a pixel missing the metal patch from the complete array.



(a)



(b)



(c)

Fig. 2. Antennas which are sound or erroneous (a)Reference geometry of the array antenna (b)Antenna with 2 or 4 defects in shape (c)Antenna with 6 or 12 defects in shape

With reference to Figure 2(a) as a perfect array antenna, imperfection is assumed that there are 2 or 4 faulty pixels as in Figure 2(b) and 6 or 12 erroneous pixels as in Figure 2(c)..

III. FINDING ERRORS AND CLASSIFICATION

The work is carried out as the following flowchart says.

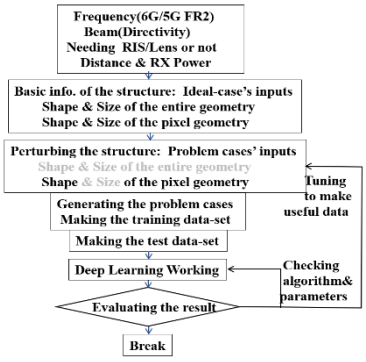
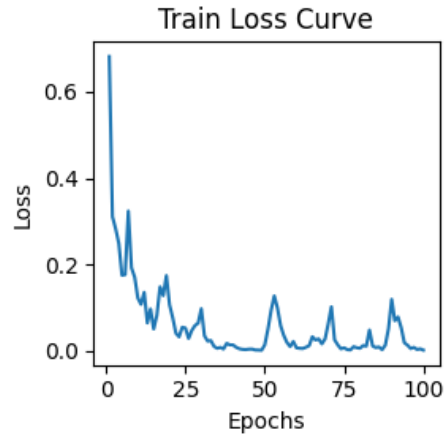
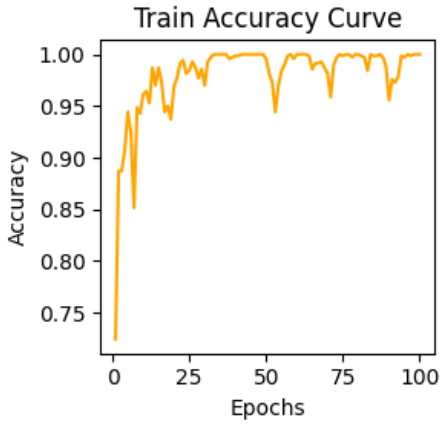


Fig. 3. The diagram which describes the flow of the work

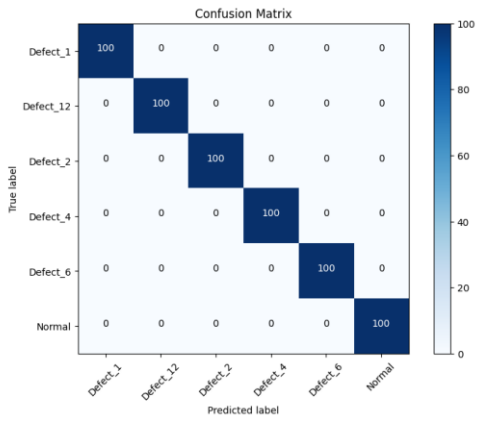
Before the work starts, the perfect array antenna as the ideal case is determined by the mobile user requirements such as the frequency, distance between the TX and RX and received power related to performances of beamforming. The geometrical information like the shape and size of the entire and elements of the antenna is obtained. The data-set is generated by perturbing the geometry of the ideal case, that is to say, discarding 2 or 4 or 6 or 12 patches from the perfect array. The test data are added to those training data.



(a)



(b)



(c)

Fig. 4. Features and results of applying the deep learning method to detect and classfy the defects on the ntennas (a)Loss vs. epoch (b)Accuracy vs. epoch (c)confusion matrix

Deep learning program named ResNet18 provided by Pitorch is applied to check the kinds of the defects assumed as previously. Figures 4(a) and (b) are loss function and accuracy level as the epoch progresses. Considering relatively a small number of data trained and tested, there occur some spikes as the epoch is developing, but the function of classification on the kinds of the defects is working properly as observed in the confusion matrix of Figure 4(c). Lastly, the effect of the defects will cause the antenna of the communication system to have is presented. Electromagnetic calculation is conducted.

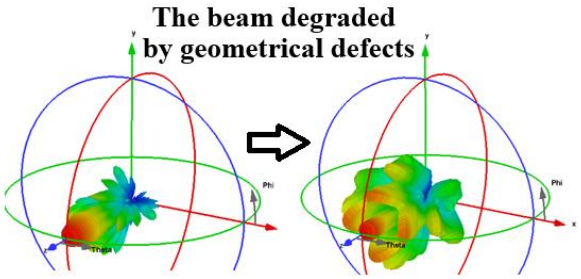


Fig. 5. The beam pattern of the ideal antenna and that of an imperfect one

The EM simulations in Figure 5 reveal the beam pattern of the perfect antenna is directive, while the antenna with defects loses directivity. Care must be taken of when an antenna is manufactured and they must check geometrical errors there.

IV. Conclusion

Deep learning program has been adopted to identify geometrical errors in the array antenna in case of the degraded quality of mobile communication. While most of the areas of communication using the AI are limited to designing the optimal architecture of a network and assigning the resources off-loading, etc., the deep learning has been brought to solve a hardware problem. The kinds of the defects are identified and the classification will help antenna and system developers track the causes of mal-function in the wireless communication.

Acknowledgment *(Heading 5)*

This work is supported by the MSIT(Ministry of Science and ICT), Korea under the ITRC (Information Technology Research Center) support program (IITP-2025-RS-2025-00259061121821038201O1) supervised by the IITP (Institute for Information & Communications Technology Planning & Evaluation)page.

References

[1] kamalakshi Deshmukh, "White Paper on ChatGPT: A Comprehensive Overview," Medium, Jun 15, 2023

[2] Arash Heidari et al,, "Deepfake detection using deep learning methods: A systematic and comprehensive review," Wiley Interdisciplinary Reviews, No.11, 2023

[3] Anzhella Pankratova, "Computer Vision In Self-Driving Cars," OpenCV.ai, December 19, 2023.

[4] Mathworks, "Deep Learning Using Synthesized Data for Communications and Radar," White Paper, 2019.

[5] D. A. Sánchez-Hernández, S. R. Best, M. M. Tentzeris, S. Kahng, G. F. Pedersen , "Smart Antennas for 5G+," ISBN: 978-1-394-21052-7, 2024, Wiley-IEEE Press.