

A 28-GHz Wideband 2×2 U-Slot Patch Array Antenna

Nanae Yoon · Chulhun Seo*

Abstract

In this study, a 28-GHz U-slot array antenna for a wideband communication system is proposed. The U-slot patch antenna structure consists of a patch, two U-shaped slot, and a ground plane. With the additional U-slot, the proposed antenna has around 10% of bandwidth at -10 dB. To increase gain, the U-slot antenna is arrayed to 2×2. The proposed antenna is designed and fabricated. The 2×2 array antenna volume is 41.3 mm × 46 mm × 0.508 mm. The proposed antenna was measured and compared with the simulation results to prove the reliability of the design. The bandwidth and gain of the measurement results are 3.35 GHz and 13 dBi, respectively and the operating frequency is around 28 GHz.

Key Words: 28 GHz, 5G, Antenna, U-Slot, Wideband.

I. INTRODUCTION

The development of a 5G system has been begun recently to obtain higher data rates. The standardization activity of 5G is expected to be available in the early 2020s. Compared with a 4G system, the 5G system uses millimeter-wave bands, which are a challenging requirement in the design of an antenna in 5G mobile systems. As the mobile industry looks toward scaling up into the millimeter-wave spectrum, carriers are likely to use the 28, 38, and 73 GHz bands that will become available for future technologies [1–3].

Microstrip antennas have become attractive for use in mobile applications. This antenna has attracted much interest because of its low profile (i.e., compact size), light weight, low cost mass production, and ease of installation. However a major limitation in its application is its narrow bandwidth. The technique that has been used extensively for increasing bandwidth is stacked patches, in which a parasitic element is placed vertically over the lower patch. A microwave antenna that introduces a U-slot or slit into a rectangular radiating patch is a simple and efficient

method for obtaining the desired compactness and multiband and broadband properties, as this shape radiates electromagnetic energy efficiently. This design avoids the use of stacked or parasitic patches, and etching U-slot on the patch is simple [4–7].

A 2×2 U-slot patch is used to obtain the design characteristic of a wide bandwidth and a simple structure at around 28 GHz. This antenna frequency is a candidate band for 5G mobile communication. Two U-slots in a single patch antenna is designed, and this antenna is arrayed to increase antenna gain. The proposed structure is simpler than a stack patch, which has the characteristic of a wideband, but indicates a wide bandwidth.

II. ANTENNA DESIGN

Fig. 1 shows the conventional and the proposed single-patch antenna structures. Fig. 1(a) is the conventional rectangular single-patch antenna structure that is calculated and optimized using patch antenna equations [8]. Fig. 1(b) and (c) present the one and two U-shaped slots etched on the rectangular patch,

Manuscript received May 9, 2017 ; Revised June 20, 2017 ; Accepted July 5, 2017. (ID No. 20170509-021J)

Department of Electronic Engineering, Soongsil University, Seoul, Korea.

*Corresponding Author: Chulhun Seo (e-mail: chulhun@ssu.ac.kr)

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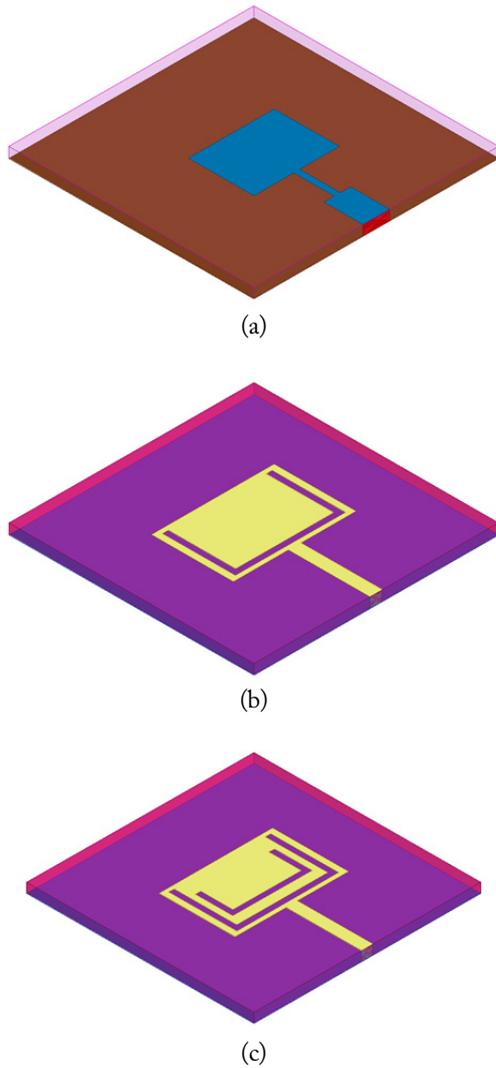


Fig. 1. (a) Conventional, (b) one-U-slot, and (c) two-U-slot single antennas.

respectively. The bottom plane is ground. The U-slot patch introduces an additional resonance frequency [9-10]. Therefore, for ease of control frequency, the antenna with two U-slots is selected. The substrate of the antenna is a Rogers RT/Duroid5880, which has permittivity of 2.2. The dimensions of the conventional antenna and proposed structure are the same to 12 mm × 12 mm × 0.508 mm. The rectangular patch sizes are

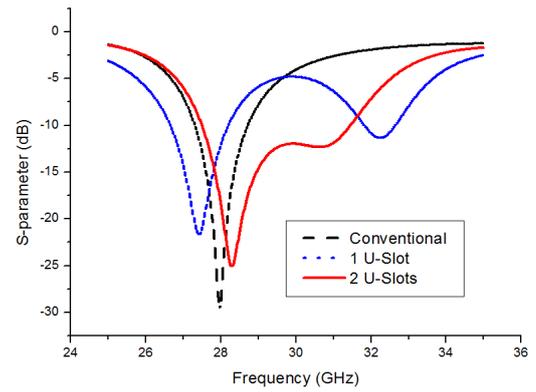
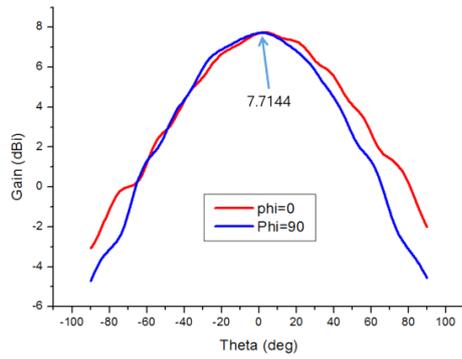


Fig. 2. Simulation result of the single-patch antenna (S -parameter).

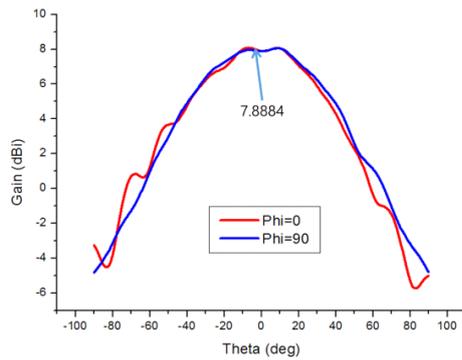
different. The conventional patch size is 4.2 mm × 3.2 mm and the proposed patch size is 6 mm × 4 mm. The slot thickness of proposed antenna is 0.3 mm. As the operating frequency is high, it needs to be designed with a simple structure; therefore, a microstrip feeding line is used. The antennas are simulated using the ANSYS HFSS EM simulator. Fig. 2 illustrates the characteristic of the S -parameter simulation results. The black and blue dash lines represent the S_{11} of the conventional antenna and the one-U-slot patch antenna, respectively. The red solid line is the S_{11} of the proposed antenna. Consequently, the proposed two-U-slot structure obtains a wide bandwidth. The one-U-slot structure has a dual-band frequency. However, as our purpose is to obtain a wide bandwidth, we consider the two-U-slot structure. The proposed structure with two U-slots has a 27.5–31.44 GHz bandwidth, which is approximately 13.36% bandwidth (3.94 GHz) with a center frequency of 29.47 GHz. Fig. 3 shows the simulation results of the radiation pattern. To compare the gain, we indicate the radiation pattern of all structures at the same frequency of 28 GHz. The proposed structure has the highest gain. Comparing the conventional with the proposed structure, the proposed patch size is larger than the conventional one. However, it increases to around 1.8 times more than the conventional patch. The proposed structure has a wider bandwidth than and the highest gain among the three antennas with the same size. Table 1 compares the proposed and conventional antennas. The proposed antenna has a higher

Table 1. Comparison between single and array antennas

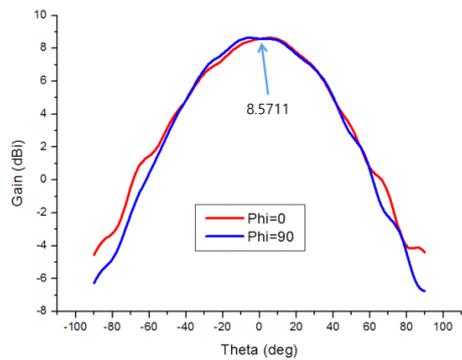
	Conventional	1 slot	2 slots	2×2 simulation	2×2 measurement
Patch size (mm)	4.2 × 3.2	6 × 4	6 × 4	6 × 4	6 × 4
Center frequency (GHz)	28.01	27.42 / 32.24 (Dual-band)	29.47	29.01	28.43
Bandwidth (%)	4.93	5.54 / 2.48 (Dual-band)	13.37	14.27	11.8
Gain @28 GHz (dBi)	7.71	7.89	8.57	14.30	13



(a)



(b)



(c)

Fig. 3. Simulation result of the single-patch antenna (radiation pattern): (a) conventional, (b) one-U-slot, and (c) two U-slots.

gain and a wider bandwidth than the conventional antenna.

To increase the gain, the proposed antenna is arrayed to 2×2 as shown in Fig. 4. Each patch distance is greater than the half wavelength because of the reduced mutual coupling effect. The S -parameter and radiation pattern simulation results are presented in Fig. 5 [11–14]. The simulation result shows that the bandwidth is 26.94–31.08 GHz (14.27%), and the radiation pattern result indicates a gain of 14.30 dBi. The array antenna has the characteristic of a wide bandwidth. The gain increased to 6 dB because the antenna is arrayed to 2×2 .

III. EXPERIMENT

Fig. 6(a) and (b) show the fabricated proposed structure its

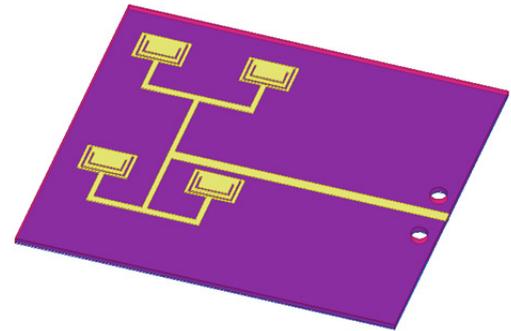
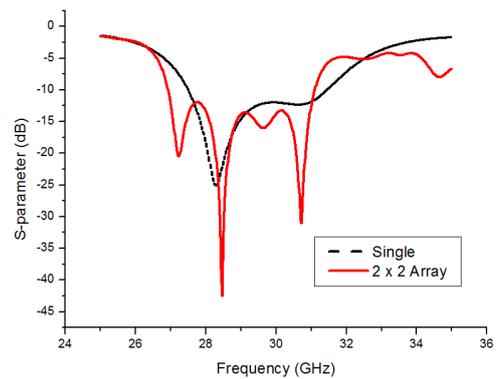
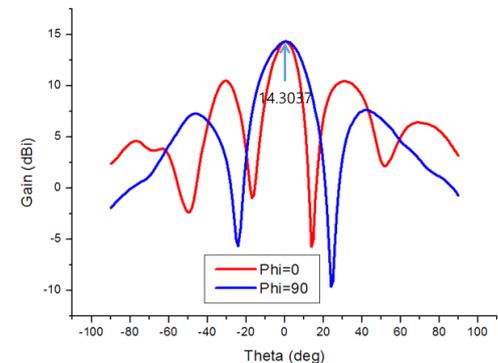


Fig. 4. The proposed 2×2 array antenna.



(a)



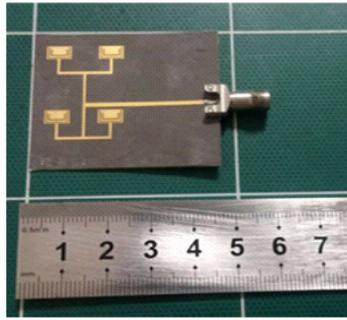
(b)

Fig. 5. Simulation results of the proposed antenna: (a) S -parameter and (b) radiation pattern.

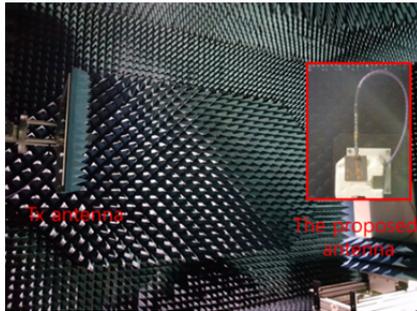
measurement setup, respectively. For measuring, the port is connected. The proposed antenna is measured using a network analyzer and a far-field antenna chamber. The measurement results are presented in Fig. 7. Fig. 7(a) illustrates the S -parameter with the simulation result. The bandwidth obtained is 11.8%. As shown in Fig. 7(b), the radiation pattern of the proposed antenna is about 13 dBi. Table 1 compares the simulation and measurement results. A good agreement is observed between simulated and the measured results.

IV. CONCLUSION

This study proposes two 2×2 U-slots array patch antenna for

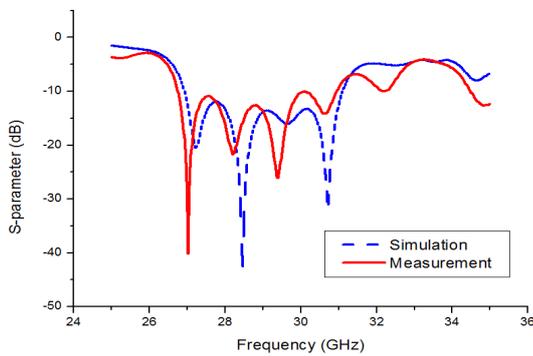


(a)

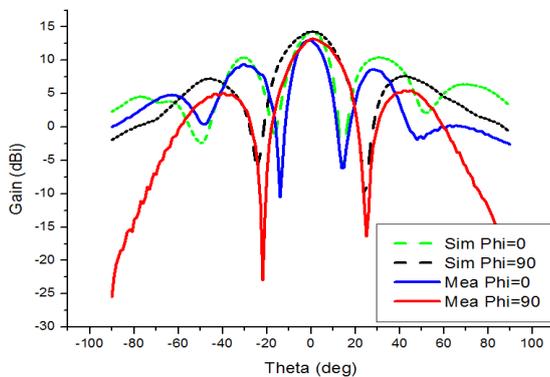


(b)

Fig. 6. Fabrication and measurement of the 2×2 U-slot patch array antenna: (a) fabrication and (b) measurement setup.



(a)



(b)

Fig. 7. Measurement results of the proposed antenna: (a) S -parameter and (b) radiation pattern.

a wide band communication application. The operating fre-

quency is around 28 GHz for a 5G system candidate. Compared with the conventional and one-U-slot antenna, the proposed antenna has a wide bandwidth of 11.8% and high gain of 13 dBi. This antenna is an ideal candidate for 5G mobile system applications.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIP) (No. NRF-2017R1A5A1015596).

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Nanae Yoon



received her B.S. degree in electronics engineering from Kangnam University, Korea in 2011 and her M.S. degree in electronics engineering from Soongsil University, Korea, in 2013. She is currently pursuing the Ph.D. degrees in Information and Communication Engineering at Soongsil University, Seoul, Korea.

Chulhun Seo



received B.S., M.S., and Ph.D. degrees from Seoul National University, Seoul, Korea, in 1983, 1985, and 1993, respectively. From 1993 to 1995, he was with the Massachusetts Institute of Technology (MIT), Cambridge, MA, USA, as a Technical Staff Member. From 1993 to 1997, he was with Soongsil University, Seoul, Korea, as an assistant professor. From 1999 to 2001, he was with MIT as a visiting professor. From 1997 to 2004, he was with Soongsil University as an associate professor. Since 2004, he has been a professor of electronic engineering with Soongsil University. He was IEEE MTT Korea Chapter Chairman from 2011 to 2014. He is the President of the Korean Institute of Electromagnetic Engineering and Science (KIEES) and Dean of Graduate School at Soongsil University. He is the director of the Center for Intelligent Biomedical Wireless Power Transfer supported by the National Research Foundation of Korea (NRF) grant funded by the by the MSIP. His research interests include wireless technologies, antenna, and metamaterials.