SEMARAK ILMU
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Journal of XX

Journal homepage:
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ISSN: XXXX-XXXX

Wearable Antenna for Military Attire

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ARTICLE INFO

Article history:
Received 29 October XXXX
Received in revised form 1 December XXXX
Accepted 9 December XXXX
Available online 10 December XXXX

Keywords:
ISM Band Antennas; Button Antenna; Radiation Pattern; S-Parameter; Military Antenna

ABSTRACT

This paper proposes a design of a dual-band button antenna with miniaturised structure. The button antenna is designed and simulated at Industrial Scientific Medical (ISM) band resonant frequency of 2.45 GHz and 5.8 GHz to be used with military garments epaulettes. The material and parameters of structure have been chosen and calculated so that the antenna is radiating with omnidirectional radiation pattern. The simulated gains of the antenna are 3.97 dBi and 7.52 dBi for the two resonating frequencies, respectively. The front to back ratio (f/b) for both frequencies are higher than 10 dB. The maximum beams are directed at 51° and 108° respectively for E-plane, and 29° and 59° respectively for H-plane. The simulations have been performed by using Computer Simulation Technology (CST) software.

1. Introduction

Antennas are essential elements of communication, and advancement of antennas have been a significant achievement in the field of communication. Even though the technology evolves and become more advance day by day, private and government sectors still have space to enhance their communication technology implementation as they are still using manual organisation system such as thumbprint or punch card for attendance. It is a time for these sectors to embed their employee's identification system onto their daily working garments so they can be tracked within the working compound. This tracking capability will require an antenna which is embed-able with their attires. Thus, it is a quest for antenna researchers to propose new antenna designs for adaptive wearable antenna. A general method for expressing an antenna's performance is the pattern of radiation that is a graphical representation of an antenna's radiation properties as a function of visual coordinates. With the right design, radiation pattern can be optimised so that it will produce directive of even omnidirectional radiation pattern. Due to the massive potential in a wide range of applications, wearable devices have gained more and more attention recently.

In recent years, the researcher has done many studies include wearable physical button antenna, patch button antenna, conductive patch textiles and so on [1]–[17]. Some studies focus on the antenna's miniaturisation, and some others focused more on the antenna bending degree. There are many research studies on button antenna such as cuff button, monopole button, patch button and G-shape button. Most of the research studies were designed on the dual-band or triple-band resonant frequency with focusing on the efficiency of reflecting coefficient, the effect of button size and impact of bend antenna. Their researches are concentrated on civilian purpose, where the button antenna was implemented on shirts or pants [1], [16]. Todays, wearable antenna design is a challenge for antenna engineers, as an inevitable coupling between antennas and human bodies, the performance of the antenna can change compared to the situation of free space. In addition, the wearable antenna length, weight, and thickness should be considered for comfortable wear and attractive appearance as the aesthetic value and camouflage capability are also factors to be considered.

Therefore, this project is aimed to propose a new design of a button antenna to be used with military garments, which specifically meant for military epaulettes. There is one research that closely like this research work which is from author H. Lee. The research focused on military purpose with the antenna was implemented on a beret, combat helmet and small missile surface at low single band frequencies resonated at 1.58 GHz and 0.92 GHz [18], [19]. However, these frequencies are resonated outside ISM band range.

In this paper, a dual-band ISM button antenna is proposed at resonating frequency of 2.45 GHz and 5.8 GHz. This antenna is expected to resonate with omnidirectional radiation pattern as in [1], [2], [20]. The button antenna was constructed, such as circle like-button on military garments epaulette.

2. Antenna Geometry and Design

The design and configuration of the button antenna had gone through different adjustments within optimization phase to achieve targeted resonant frequency and bandwidth. The button antenna consists of a 13 mm diameter button with a thickness of 5.2 mm. Due to the availability of polyamide buttons, the substrate material selected is Rogers RT5880 which has the lowest dielectric constant and deficient absorption of moisture suitable to our project [3]. The pin has a partial metal plane. Several designs were simulated using Computer Simulation Technology (CST) Software. Figure. 1 shows the geometry of the proposed antenna.

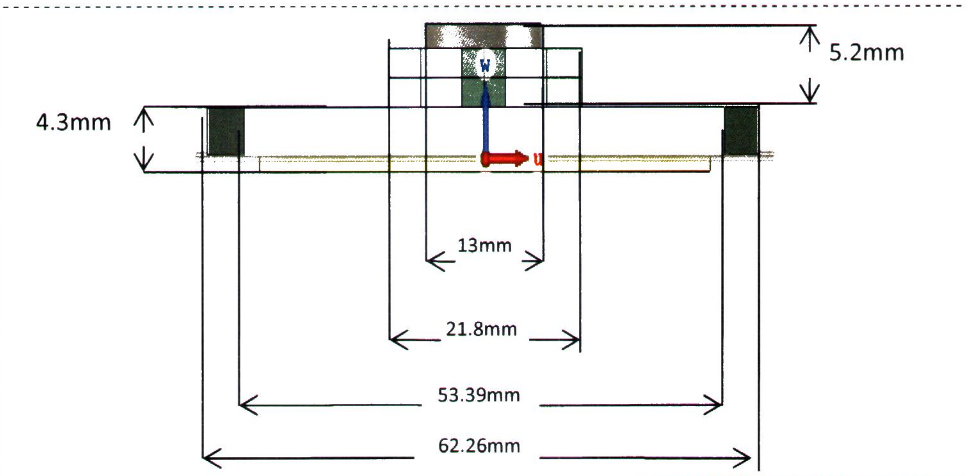

Fig. 1. Geometry design of button antenna

The geometry design of the button antenna is referred to military epaulette as shown in Figure 2 (a). The antenna geometry consists of the conductive patches on the bottom plane and the ground on the topflight, as shown in Figure 2 (a) and Figure 2 (b), respectively.

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Volume XX, Issue X (2019) XX-XX

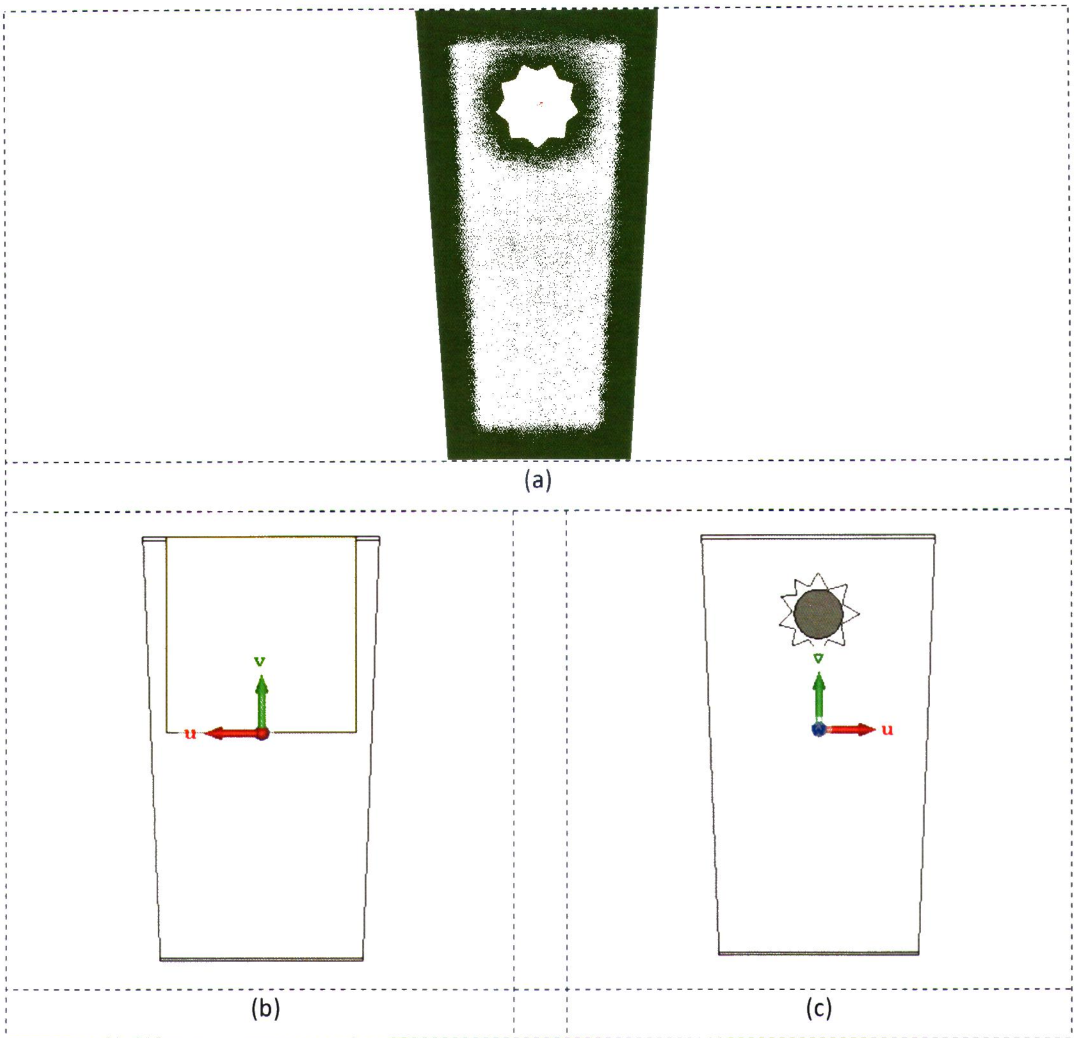

Fig. 2. Structure design of button antenna based on military epaulette: (a) Military epaulette of Major rank, (b) Back view, (c) Top view.

The antenna is designed on a known substrate (ε_r = 2.2) with a thickness of 4.3 mm. The details of the antenna dimension and parameter are shown in Table 1. The parameter values were based on the actual epaulette dimension; however, the radiator and the ground were optimized to gain optimum radio performances.

Table 1
Dimension of Button Antenna

Parameter	Value	Parameter	Value
Epaulette height	9.05 mm	Button's height	5.02 mm
Copper width	53.39 mm	Epaulette' width	62.26 mm
Button width	21.08 mm	Circle width	13.00 mm

3. Methodology

After future studied on related theory and methodology, selected design criteria of material for the structure of the wearable patch antenna are an essential step towards achieving the desired results of compliance with the objective. The material rules that need to be studied are the behaviour of dielectric constant and ground plane [3], [5], [21]. On the simulation, the thing that needs to be studied is the performances of reflecting coefficient, directivity and realised gain and radiation pattern [22]. The dimensions of the antenna were calculated using a theoretical method according to the operating frequency and the necessary bandwidth and gain. Then, it was synchronised with the actual aspect of epaulette [23].

Antenna structure is designed using CST software according to the exact button epaulette measurements and parameters to simulate the antenna and observe the different parameters such as current distribution, radiation pattern, gain versus frequency curve, VSWR, loss of return [24], [25]. The results and various parameters to obtain the desired frequency operation were observed. Data processing was performed to analyse the collected data of radiation pattern using MATLAB [26], [27].

4. Specifications

The main principal parameter for patch antenna configuration is the targeted operating frequency, (f_o) where the antenna resonant frequency shall be chosen accordingly. The chosen frequencies for the ISM Band are 2.45 GHz and 5.8 GHz. Therefore, the designed antenna must be capable to operate at this two designated frequencies. The dielectric material selected for our design is ROGER RT5880 which has a dielectric constant of 2.2. Since it has the most modest losses, a substrate with the lowest dielectric constant was chosen. Table 2 shows that Rogers RT5880 has the lowest dielectric constant among all four materials and a deficient absorption of moisture that is suitable for our project.

Table 2
The materials compared where Rogers 4003, FR4, Taconic CER-10 and Rogers RT5880 [3]

Parameter	Rogers 4003	FR4	CER-10	Rogers RT5880
Dielectric constant	3.55	4.7	10	2.2
Dissipation Factor	0.0027	0.14	0.0035	0.0004
Volume Resistivity (Mohm/cm)	1.7×10^{10}	1×10^{8}	2.1×10^{8}	$\mathbf{2\times10^{7}}$
Moisture absorption (%)	0.06	0.1	0.02	0.02
Dimensional Stability (mm/mm) Parameter	<0.3	<0.04	-0.0002	-
Thermal conductivity (W/m/k)	0.71	-	0.63	0.20

For the antenna to be used in military epaulette, the antenna must not be bulky and must be easy to be integrated and carried. Therefore, the optimized dimension of the button epaulettes antenna is 4.3 mm and 53.39 mm respectively, which can be integrated with the real epaulette.

5. Result

The radiation patterns observed in this study are significant as they provide insights into the performance of the E-plane and H-plane frequencies. The correspondence of the radiation patterns in the broadside direction, as shown in Figure 3 and Figure 4, suggest a level of symmetry between the two frequencies. This symmetry is further evidenced by the similar beamwidths of -3 dB ± 79.6° and ± 43.6° respectively for 2.45 GHz and 5.8 GHz. The front-to-back ratio (f/b), which is less than 10 dB for 2.45 GHz and slightly higher for 5.8 GHz, indicates a balance in the radiation pattern.

This balance is crucial for ensuring consistent performance across different frequencies. The maximum beams for 2.45 GHz and 5.8 GHz, guided at a range of 29° and 59° correspondingly, further highlight the consistency in the radiation patterns. This consistency is a key factor in the reliable performance of the frequencies.

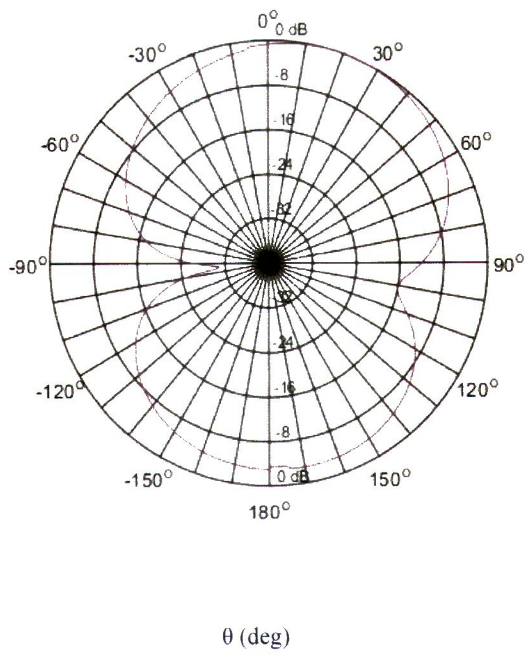

Fig. 3. Normalized elevation plane radiation patterns, $\mathbf{E}_\theta$ component at 2.45 GHz of button antenna

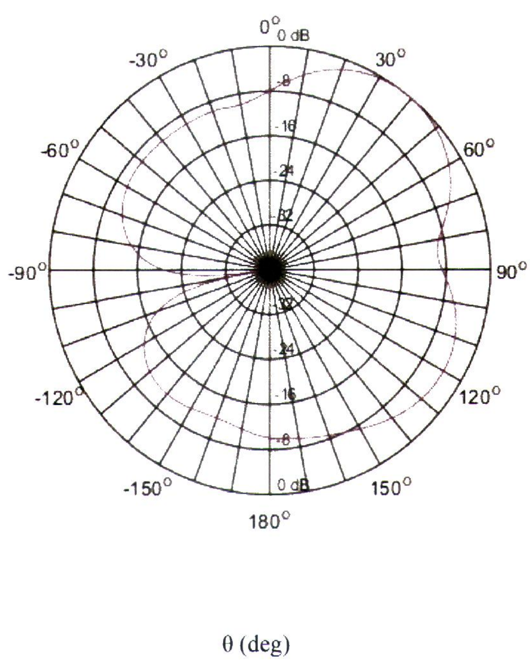

Fig. 4. Normalized elevation plane radiation patterns, $\mathbf{E}_\theta$ component at 5.8 GHz of button antenna

On the other hand, the radiation pattern of the two frequencies in the H-plane presents a different scenario. As depicted in Figure 5 and Figure 6, the -3 dB beamwidths are ± 50.1° and ± 22.2° for 2.45 GHz and 5.8 GHz, respectively. Despite the difference in beamwidths, both frequencies exhibit an excellent front-to-back ratio (f/b) which is above 10 dB. This suggests that the frequencies maintain a high level of performance even with varying beamwidths.

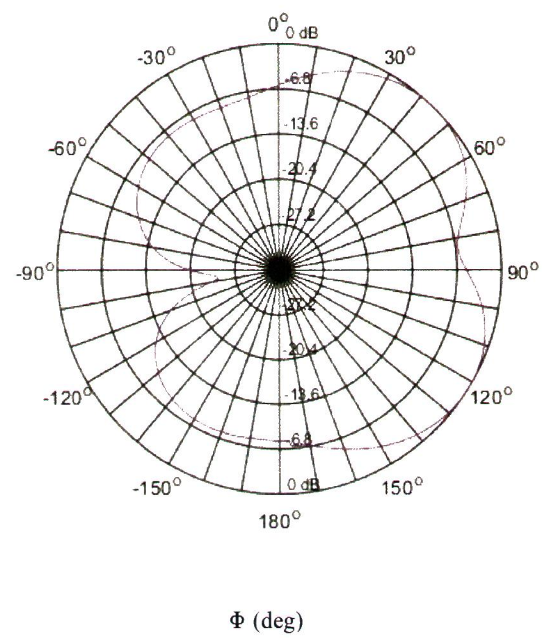

Fig. 5. Normalized azimuth plane radiation patterns, $\mathbf{E}_{\theta}$ component at 2.45 GHz of button antenna.

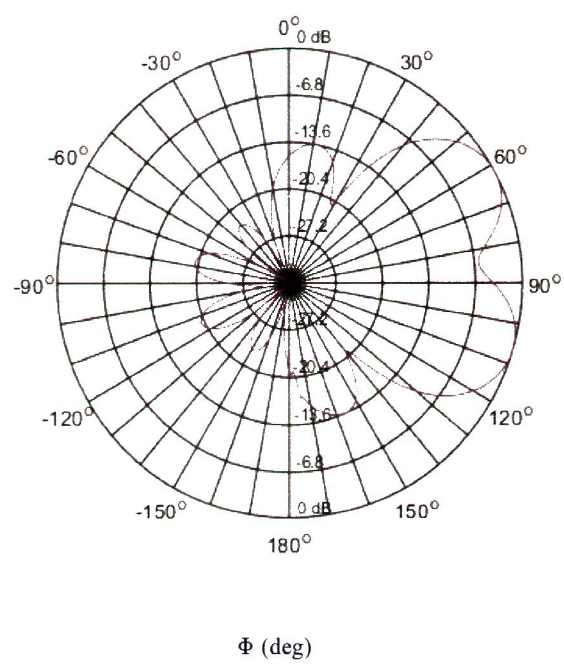

Fig. 6. Normalized azimuth plane radiation patterns, $\mathbf{E}_{\theta}$ component at 5.8 GHz of button antenna.

Based on Figure 7, it is conformed that the designed antenna is transmitting well at dual frequencies. It is proven since the behaviour of the S-parameter of the two resonant frequencies spanning from 2.4 GHz to 2.5 GHz and from 5.73 GHz to 5.88 GHz, which is having deep dive of S_{11} at -22 dBi and -24 dBi, respectively.

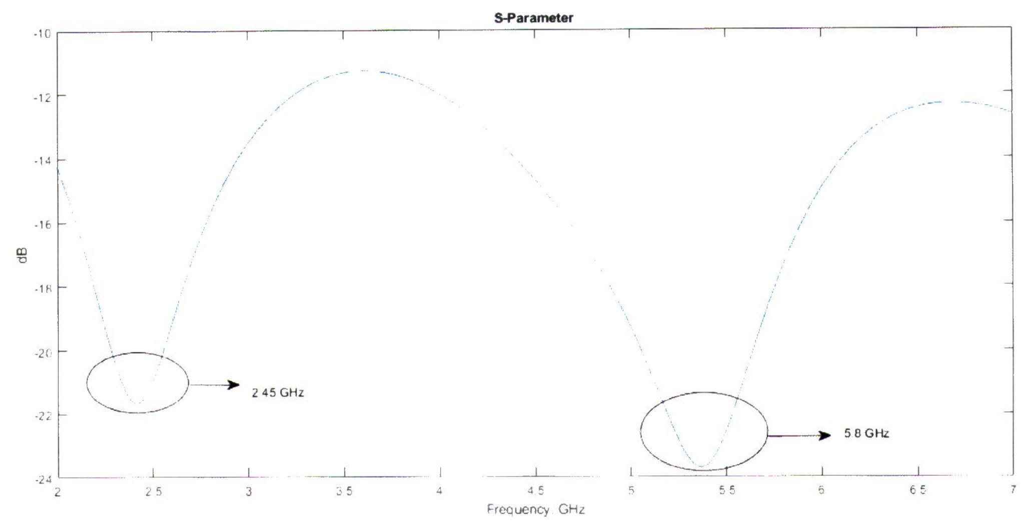

Fig. 7. S-Parameter of button antenna in CST simulation

Antenna gain is a measure of the antenna ability to direct or focus radio frequency energy on a specific direction or pattern. It essentially quantifies how much power is transmitted from an isotropic source towards the peak radiation. The gain considers the actual losses that occur. In the context of antennas, high gain is not always desirable. If the path of the desired signal is known, a high gain antenna would be beneficial. However, if the signal path is uncertain, a low gain antenna would be more suitable. The button antenna in this study produces a quasi-omnidirectional pattern with gains of 3.97 dBi and 7.52 dBi at 2.45 GHz and 5.8 GHz respectively, as depicted in Figure 8. This indicates that the button antenna can maintain a consistent radiation pattern across different frequencies.

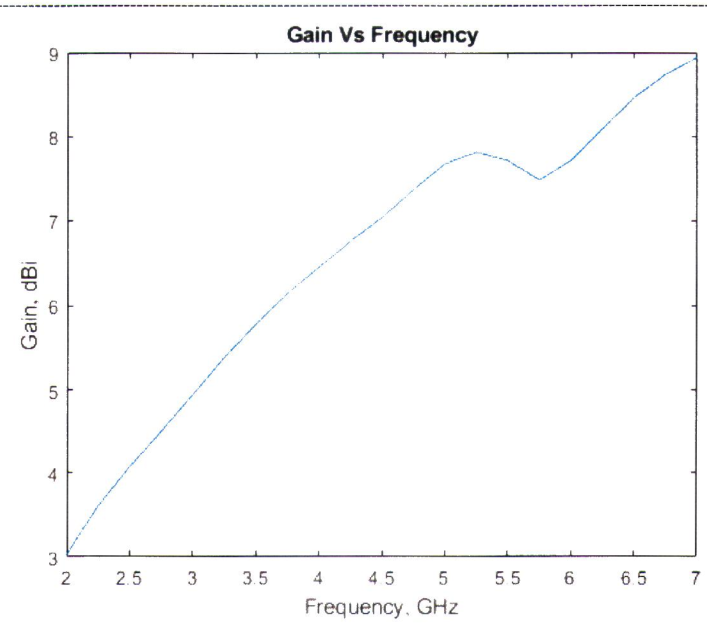

Fig. 8. Antenna gains at 2 GHz to 7 GHz

Table 3 provides a summarized various radio parameters for both the E-Plane and H-Plane at 2.45 GHz and 5.8 GHz. The result enhances our comprehension of frequency performance and holds substantial potential for influencing future research and practical applications. Additional studies could investigate these patterns in diverse contexts and assess their effect on the performance of various antenna types.

Table 3
Radio Performance

Parameter	**E-Plane**		**H-Plane**	
	2.45 GHz	**5.8 GHz**	**2.45 GHz**	**5.8 GHz**
The -3 dB beamwidths	± 79.6°	± 43.6°	± 50.1°	± 22.2°
f/b	8.35 dB	11.21 dB	11.17 dB	16.83 dB
Maximum beams	29°	59°	51°	108°
Gain	3.97 dBi	7.52 dBi	3.97 dBi	7.52 dBi

5. Conclusion

Although a great deal of literature has been published, so far there has been no research paper dealing with military epaulette garments, particularly in dual ISM band frequencies except in [18], [19], [28] that focus on missile warhead and berets respectively. Moreover, button antenna can also be designed as a reconfigurable beam pattern antenna. However, the reconfiguration only can be attained by mechanical approach [29]. Its omnidirectional pattern and slight beam focused pattern were the testable prediction of the reconfigurability.

In conclusion, the effect of radiation pattern and radio reflecting coefficient performances had been studied and showed that the designed button antenna with a small size, low profile and lightweight able to operate exactly at ISM band resonant frequencies which are 2.45 GHz and 5.8 GHz. Even though, not reported here, the effect of cross polarization remains small, and the front to back ratio (f/b) exceeds 10 dB. In addition, the simulated reflected radiation pattern is in good condition where H-plane at 5.8 GHz has higher maximum beam with 7.52 dBi gain.

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