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Wi-Fi 6E Antenna Design for All-metal Housing of Notebook

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In this paper, we present two antenna structures with the Wi-Fi 6E band, namely, dual-slot and single-slot antennas. The presented antennas can be applied for the all-metal housing on notebook computers and also meet the requirements of notebook computer antenna design for industry. First, we introduce the design of the dual-slot antenna at the top of the metal case. The size of the dual-slot antenna was $53 \times 6 \times 0.6$ mm^3. To meet the specifications of commercially available 13-inch laptops, we chose a $305 \times 205 \times 1$ mm^3 metal case in the simulation environment. To make our proposed antenna design meet the requirement that the reflection coefficient of the Wi-Fi 6E frequency band is lower than -10 dB, we adjusted the grounded parasitic element and antenna structure to achieve the coupling effect of the slot. This antenna achieved a high screen-to-body ratio and narrow bezels and conformed with current notebook design trends. Next, because some laptops have IR cameras that require a smaller antenna, we introduce the single-slot antenna for use above the metal case. The size of the simulated metal case was also $305 \times 205 \times 1$ mm^3, and a monopole antenna with dimensions of $30 \times 4.5 \times 0.6$ mm^3 was used. By bending the geometry of the slot antenna, it can be modified to change the coupling effect. The antenna not only achieved a high screen-to-body ratio and narrow bezels, but was also smaller than the dual-slot antenna. The two proposed antenna architectures have the advantage of compactness, with the need to open only one or two slots on the metal case of a notebook computer for the Wi-Fi 6E band.

1. Introduction

Antennas are physical sensors of electromagnetic (EM) waves and essential components of all radio equipment. An antenna is an array of conductors (elements) electrically connected to a receiver or transmitter. Antennas can be designed to transmit and receive radio waves in all directions. In reception, an antenna intercepts the power of a radio wave to produce an electric current at its terminals for the receiver.

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Common antenna architectures applied to notebook computers include loop antennas, inverted-F antennas, and monopole antennas.(1–19) The antenna structures for loop and inverted-F antennas are simple. We can reduce the size of an antenna by the mirroring principle and combine parasitic resonance structures to increase the bandwidth. A monopole antenna, whose structure is more changeable, can couple to the grounded parasitic structure to resonate outside the low-frequency path for the fine-tuning of multiband antennas.

The following describes the antenna design applied to notebook computers in recent years. In 2021, an asymmetric and self-isolating notebook antenna with a size of 30 × 6 mm^2 was proposed by Su and Wan.(20) To improve the performance for the Wi-Fi 6E frequency band, they used a 2.4 GHz partially curved ring structure to couple with the T-shaped structure. At the same time, two Wi-Fi 6E multi-input multi-output (MIMO) antenna designs were proposed.(21) In Ref. 21, an antenna architecture with a size of 14.5 × 5 mm^2 was first proposed. The simple architecture was a 5 mm fed monopole antenna combined with the grounded parasitic architecture. To design an antenna including the Wi-Fi 6E band with the coupling capacitor, two antennas with a size of 36.5 × 5 mm^2 and similar characteristics but opposite current phases were combined to achieve miniaturization and isolation. Thakur and Tamrakar proposed a dual-band ultrathin antenna design suitable for mobile devices,(22) of which the antenna size was 134 × 2 mm^2 and the structure was 26 × 1.5 mm^2. Later, Shen and Su also proposed a single-plane multiband antenna design that can be applied to the metal backplane of notebook computers. Their proposed antenna design consisted of a parasitic ground structure and an inverted-F antenna structure that can be used in the WLAN 2.4/5 GHz band and LTE 700/900/1800.(23)

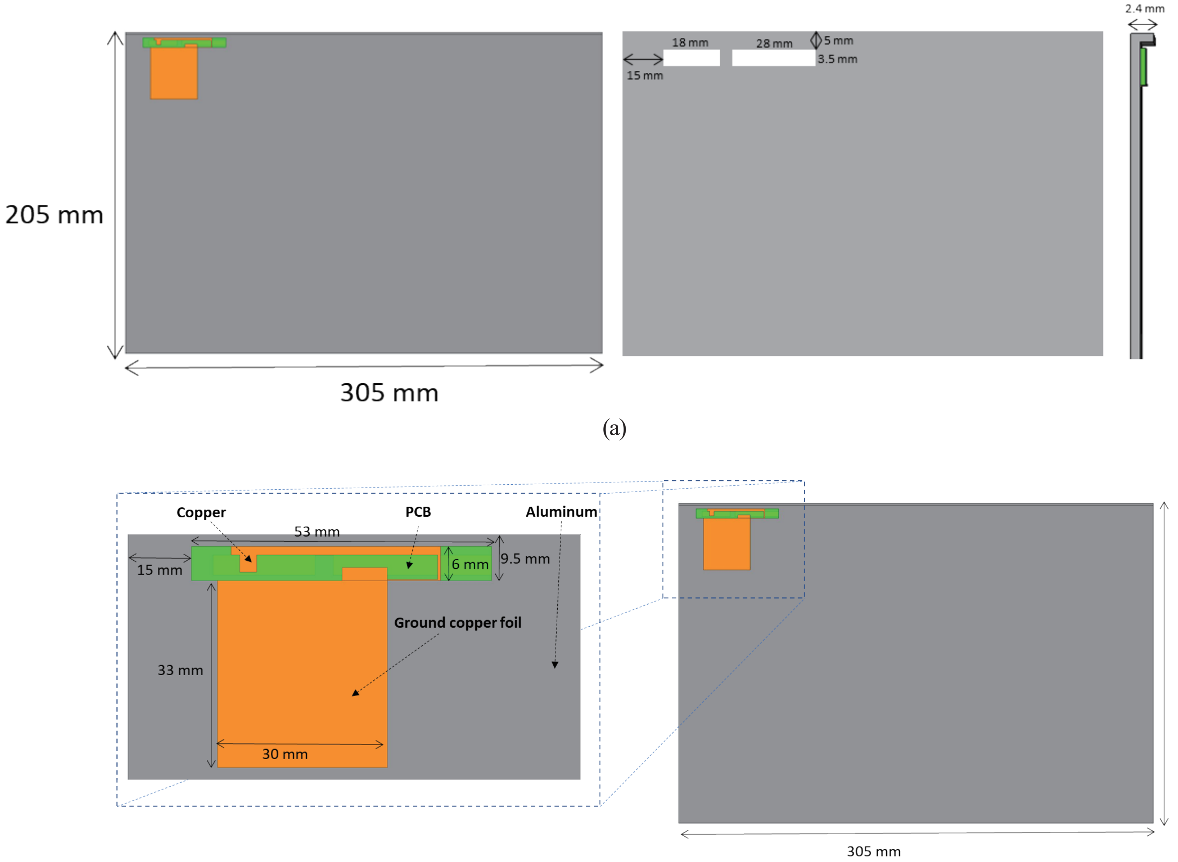
In addition, related research on the structure design of slot antennas for notebook computers has been reported.(24–31) A coupled feed method is commonly used for optimizing slot antennas by adjusting the shape or position of the coupling structure. Since the bandwidth of slot antennas is very narrow, which is a challenge in antenna design, Zhu *et al.* proposed a novel broadband microstrip-fed slot antenna that can effectively increase the bandwidth compared with that of traditional antennas.(30) The hole architecture was used to increase the antenna bandwidth.(31) Han *et al.* proposed a monopole slot antenna for notebook computers. Although the proposed antenna can completely cover the WLAN 2.4/5 GHz frequency band and Wi-Fi 6E band, its disadvantage is the low gain and efficiency of the low-frequency band.(32) However, the reflection coefficient for the −6 dB threshold is too high for engineering requirements. In this study, we therefore proposed two novel antennas with the reflection coefficient for the −10 dB threshold to meet the engineering requirement. Moreover, the area of the proposed single-slot antenna was reduced by about 50%. From our numerical results, we successfully verified that the proposed antenna designs can work in the Wi-Fi 6E band and can be used for the metal housing of a notebook.

2. Architecture and Layout for Antennas

The structure parameters for the dual-slot antenna are shown in Table 1. This dual-slot antenna for a notebook is illustrated in Fig. 1(a). The size of the first slot is 18 × 3.5 mm^2 and the size of the second slot is 28 × 3.5 mm^2. The upper edge of each slot is 5 mm below the top of the

Table 1
Antenna structure parameters of the dual-slot antenna.

Parameter	Value	Parameter	Value
FR-4 thickness	0.6 mm	Aluminum shell size	305 × 205 mm^2
Loss tangent	0.025	Thickness	1 mm
Dielectric constant	4.3	Upper edge of aluminum shell	2.4 mm



(a)

(b)

Fig. 1. (Color online) Diagram of dual-slot antenna for notebook and dimensions of slots. (a) Top view of simulated environment for notebook. (b) Dimensions of slots 1 and 2 of antenna.

aluminum shell. The dimensions of the dual-slot antenna are shown in Fig. 1(b). The dimensions of the dual-slot antenna are 53 × 6 × 0.6 mm^3, and the ground copper foil has dimensions of 33 × 30 × 0.1 mm^3 and is 15 mm from the left side of the aluminum shell. The distance between the bottom of the antenna and the upper edge of the aluminum shell is 9.5 mm. The antenna is based on the loop pattern on the front printed circuit board (PCB), and the structure is shown in detail in Fig. 2.

The parameters for the single-slot antenna are given in Table 2. This single-slot antenna for a notebook is plotted in Fig. 3(a). The slot size is 30 × 2.8 mm^2 and the upper edge of the slot is 2.5 mm below the top of the aluminum shell. The dimensions of the dual-slot antenna are shown in Fig. 3(b). The single-slot antenna has dimensions of 30 × 4.5 × 0.6 mm^3 and the ground copper

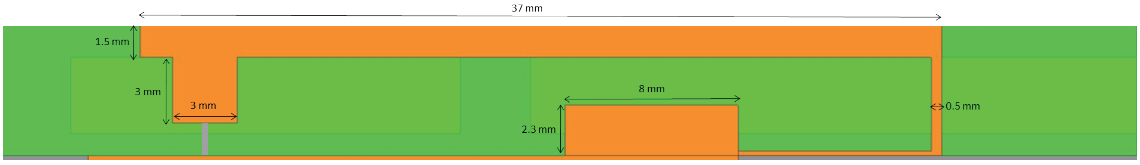
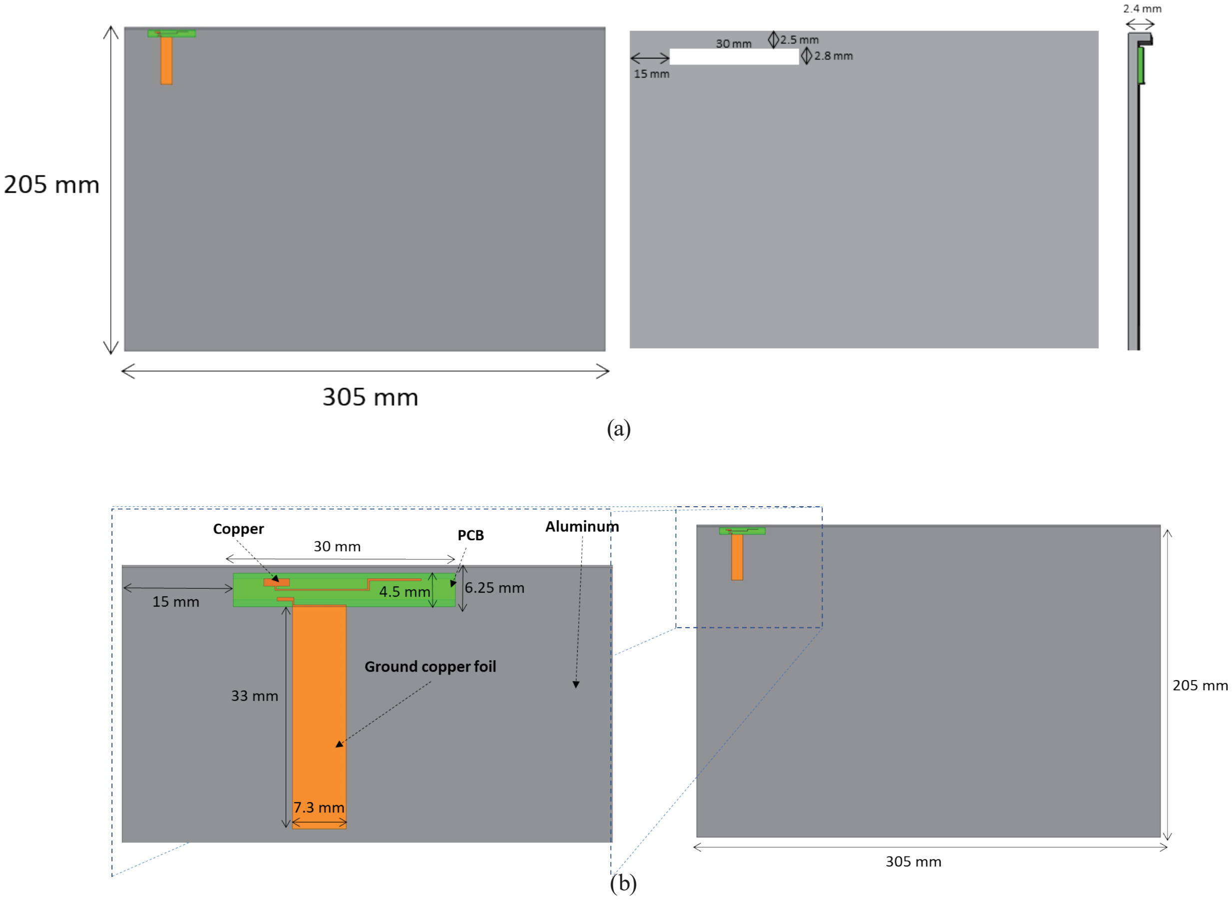


Fig. 2. (Color online) Diagram of inner structure of dual-slot antenna.

Table 2
Antenna structure parameters of single-slot antenna.

Parameter	Value	Parameter	Value
FR-4 thickness	0.6 mm	Aluminum shell size	305 × 205 mm^2
Loss tangent	0.025	Thickness	1 mm
Dielectric constant	4.3	Loss tangent	0.0004
		Dielectric constant	9.4



(a)

(b)

Fig. 3. (Color online) Diagram of single-slot antenna for notebook and dimensions. (a) Top view of simulated environment for notebook. (b) Dimensions of slot of antenna.

foil has dimensions of 33 × 7.3 × 0.1 mm^3 and is 15 mm from the left side of the aluminum shell. The distance between the bottom of the antenna and the upper edge of the aluminum shell is 6.25 mm. The monopole antenna on the front PCB and its detailed structure are plotted in Fig. 4.

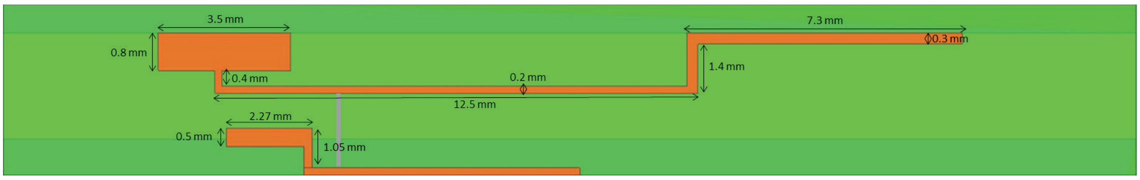


Fig. 4. (Color online) Diagram of inner structure of single-slot antenna.

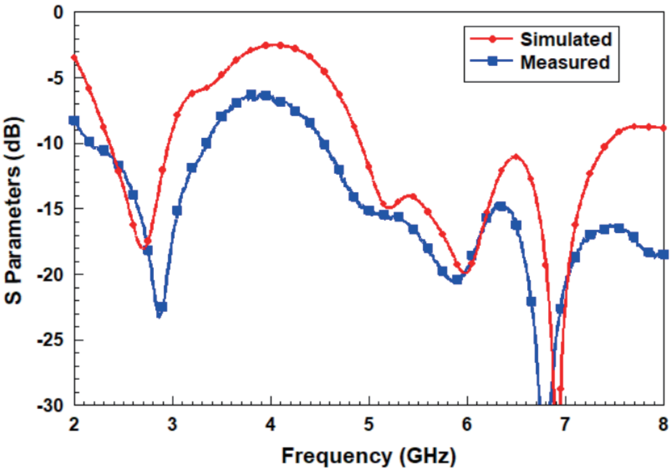


Fig. 5. (Color online) S-parameters of dual-slot antenna obtained by simulation and measurement.

3. Results and Discussion

We used CST Studio Suite EM simulation analysis software for the simulation and analysis, and we set the S-parameter (or reflection coefficient) of the antenna to less than -10 dB for the simulated target. Figure 5 shows the S-parameters of the dual-slot antenna obtained by simulation and measurement. From Fig. 5, the dual-slot antenna can achieve the Wi-Fi 6E frequency band, and the S-parameter (or reflection coefficient) is also lower than our simulation target of 10 dB.

Figures 6–8 show the average gain and efficiency graphs obtained for the dual-slot antenna by measurement. Figure 6 indicates an average gain of −3.8 to −3.6 dBi at 2.4–2.5 GHz with an efficiency of 42–43%. Figure 7 indicates an average gain of −4.1 to −3.8 dBi at 5.15–5.85 GHz with an efficiency of 39–42%. Figure 8 indicates an average gain of −4.1 to −3.5 dBi at 5.925–7.125 GHz with an efficiency of 39–44%.

Figure 9 shows the S-parameters of the single-slot antenna obtained by simulation and measurement. From Fig. 9, the single-slot antenna can achieve the Wi-Fi 6E frequency band, and the S-parameter (or reflection coefficient) is also lower than our simulation target of −10 dB.

Figures 10–12 show the average gain and efficiency graphs obtained for the single-slot antenna by measurement. Figure 10 shows an average gain of −5.3 to −4.7 dBi at 2.4–2.5 GHz with an efficiency of 30–34%. Figure 11 shows an average gain of −6.6 to −5.2 dBi at 5.15–5.85 GHz with an efficiency of 22–30%. Figure 12 shows an average gain of −6.2 to −5 dBi at 5.925–7.125 GHz with an efficiency of 23–31%.

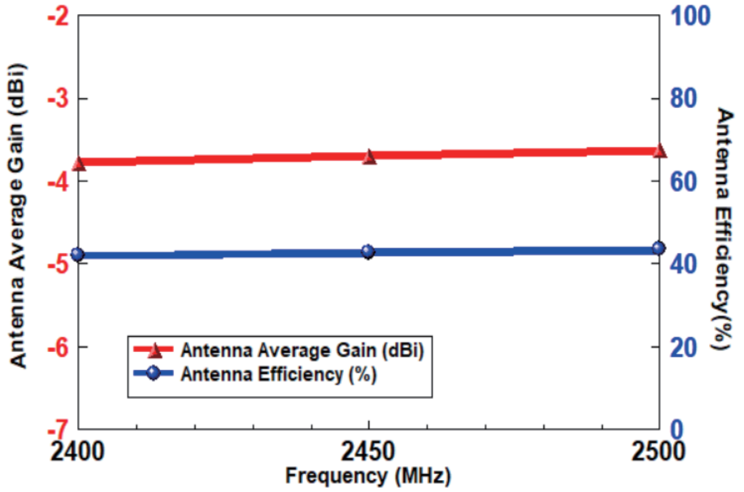


Fig. 6. (Color online) Antenna efficiency and antenna gain measured at 2.4–2.5 GHz for dual-slot antenna.

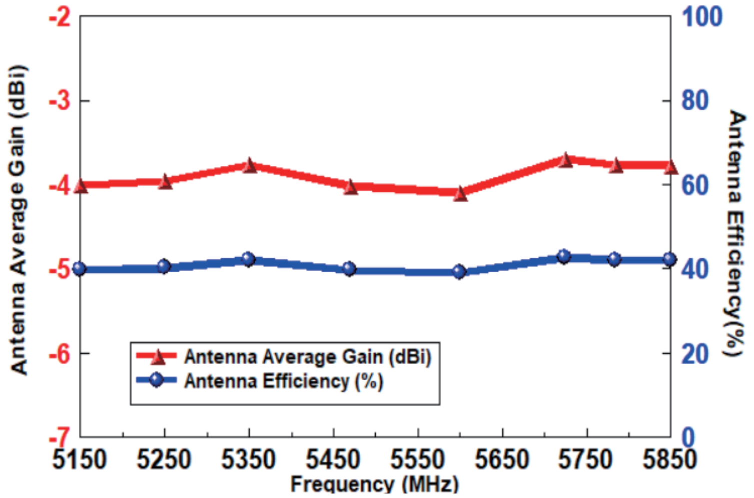


Fig. 7. (Color online) Antenna efficiency and antenna gain measured at 5.15–5.85 GHz for dual-slot antenna.

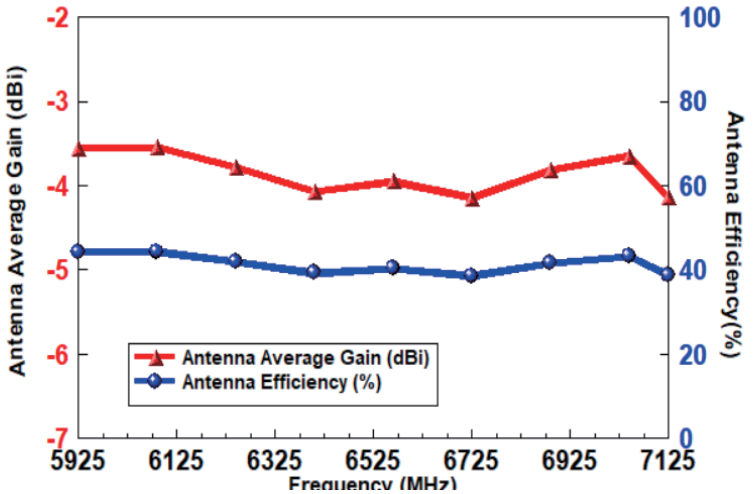


Fig. 8. (Color online) Antenna efficiency and antenna gain measured at 5.925–7.125 GHz for dual-slot antenna.

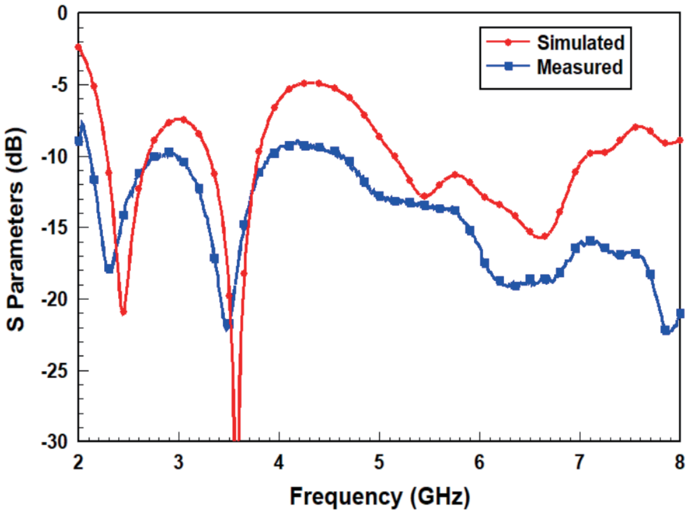


Fig. 9. (Color online) Simulated and experimental S-parameters for single-slot antenna.

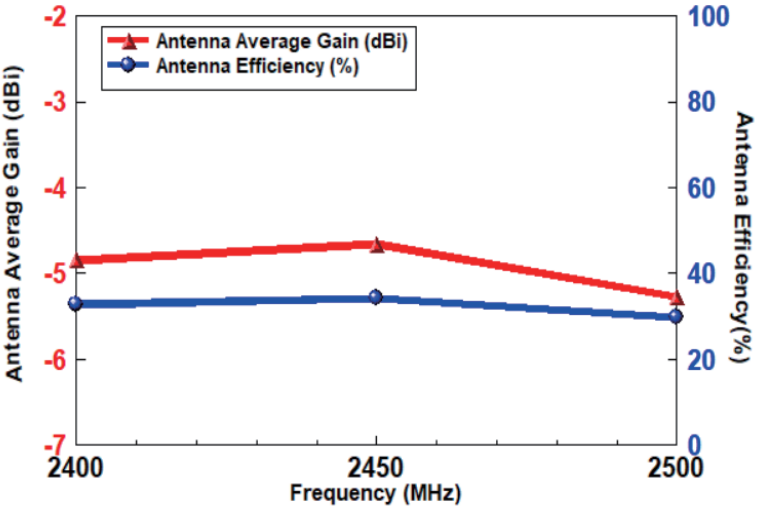


Fig. 10. (Color online) Antenna efficiency and antenna gain measured at 2.4–2.5 GHz for single-slot antenna.

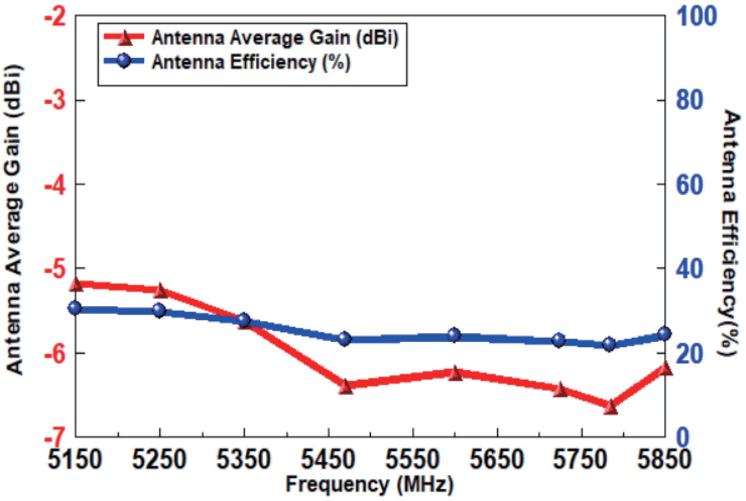


Fig. 11. (Color online) Antenna efficiency and antenna gain measured at 5.15–5.85 GHz for single-slot antenna.

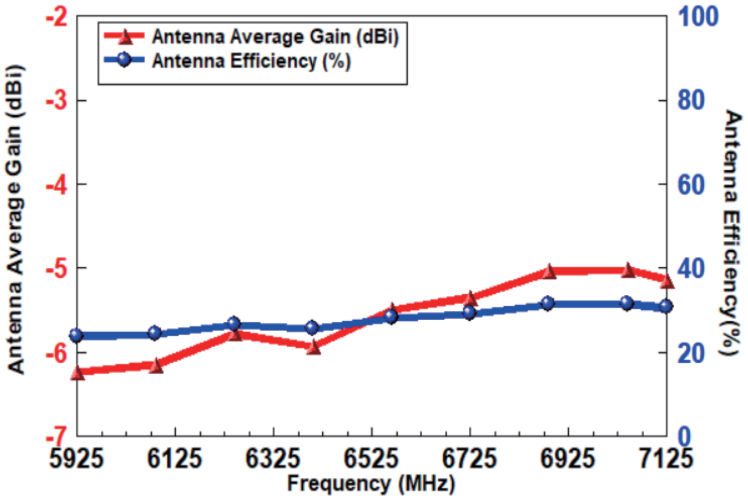


Fig. 12. (Color online) Antenna efficiency and antenna gain measured at 5.925–7.125 GHz for single-slot antenna.

4. Conclusion

In this paper, we propose two types of antennas in all-metal housing that can be applied to the design of notebook computers and achieve the Wi-Fi 6E band. Through the dual-slot hole coupling of the metal housing, the loop antenna can produce the Wi-Fi 6E frequency band. We combined the parasitic pattern and ground of the curved structure with the all-metal housing to enable the single-slot antenna to generate the frequency band of Wi-Fi 6E. These two slot antennas are simple with small dimensions and are suitable for notebooks. However, compared with the dual-slot antenna, the single-slot antenna had poorer characteristics after actual measurement because of its small size.

The small single- and dual-slot antennas were employed to achieve the band requirement for the Wi-Fi 6E frequency. These antennas on the metal shell can achieve the Wi-Fi 6E frequency, making them suitable for modern notebook designs. Our proposed antennas have high performance and are suitable for industry.

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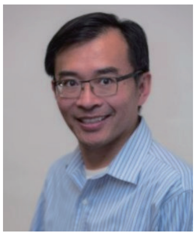

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