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LETTER

Wideband and miniaturization of antenna composed of metal case with a slot and inner folded dipole antenna

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Abstract This paper presents a antenna composed of metal case with a slot and inner folded dipole antenna. The proposed antenna structure simultaneously achieve the miniaturization of the metal case and the wide bandwidth. The impedance bandwidth of 15.9 % with the size of $0.35\lambda_0 \times 0.35\lambda_0 \times 0.03\lambda_0$ (λ_0 is the wavelength of low frequency) can be realized by the proposed structure. The proposed structure is validated by the comparison of the simulation and measurement result.

Keywords: slot antenna, folded dipole antenna, small antenna

Classification: Antennas and propagation

1. Introduction

Internet of things (IoT) application have been widespread in our lives, such as smart home, smart factories [1]. By using IoT device, all of things can connect to internet space with high data rates and low latency [2]. IoT home appliances include air conditioner, refrigerator and so on. To connect IoT device to internet, antennas are indispensable component. Antennas of home appliance is implemented anywhere, such as indoor and outdoor. The environment includes near metal plate and heat source, which affects antenna characteristics. Antenna for home appliances is required to be stable operation in such a hostile environment for antenna. To operate antenna stably, it is important that the impedance characteristics is not changed by closing the object such as metal plate. To meet this requirement, the antennas inside metal case with a slot has been proposed as cavity-backed slot antenna [3]. Cavity-backed slot antenna consists of excitation element and metal case with slot. The excitation element is employed to excite metal case with the slot. Dipole antenna and monopole antenna is usually employed for inner element. By employing compact inner element, further miniaturization can be expected. For electrically compact antenna, planar folded dipole antenna has been proposed so far [4]. In addition, the features of folded dipole antennas are high impedance characteristics. It is easy to adjust impedance matching by varying the dimensions. This paper proposes antenna composed of metal case with a slot and inner folded dipole antenna with electrically compact antenna and enhancement of bandwidth. The organization of this paper is as follows: the simulation model and dimension of proposed antenna are introduced in Section. 2. The comparison of measurement and simulation result and the comparison of related works are shown in Section 3.

2. Proposed structure

Figure 1 shows the dimensions of the proposed structure. The folded dipole antenna is in metal case as shown in Fig. 1(a). The folded dipole antenna is fabricated by dielectric substrate as shown in Fig. 1(b) and (c). The relative dielectric constant is 4.3 and tanδ is 0.003, respectively. The dimension of the folded dipole antenna are length of 23 mm, width of 23 mm and thickness of 1.6 mm, respectively. The folded dipole element is placed at center of the metal case. The metal case has H-shape slot on the surface to radiate from inner element to outside of the metal case. Figure 2 shows the current distribution. The high current density is observed around H-shape slot. This high current density is produced by the coupling between inner element and H-shape slot.

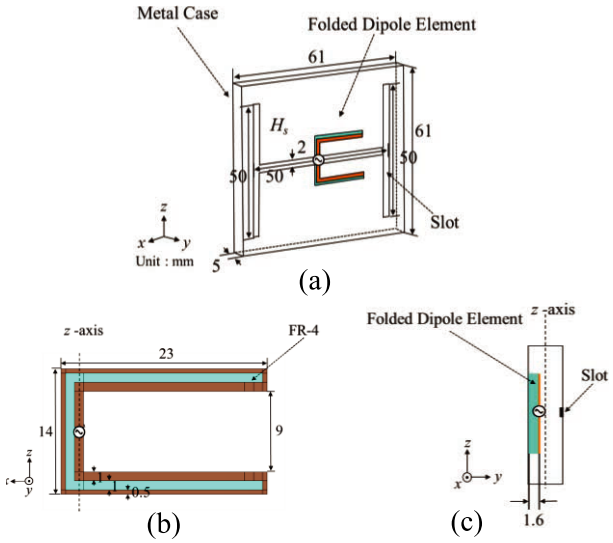

Fig. 1 Structure of proposed structure, (a) Bird's eye view, (b) top view of inner folded dipole antenna, (c) side view of proposed structure.

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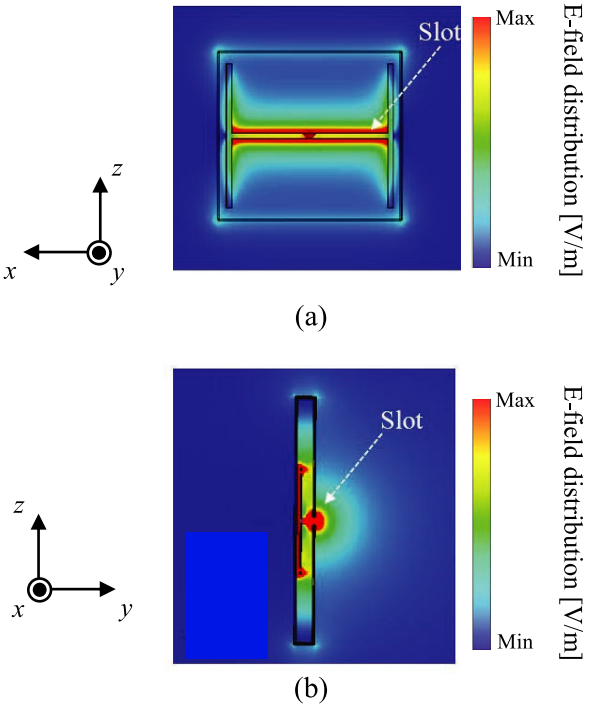

Fig. 2 Fig. 2 Current distribution of proposed structures. (a) Front view, (b) side view.

3. Measurement result and discussion

The prototype of proposed structure is shown in Fig. 3. The proposed antenna is fed by coaxial cable as shown in Fig. 3(a). The folded dipole antenna for the inner element as shown in Fig. 3(b) is inside the metal case. Figure 4 shows the comparison of simulation and measurement of VSWR. The simulation and measurement show well agreement. The operation bandwidth of proposed antenna from 15.9% can be confirmed as shown in Fig. 4. The comparison of gain is shown in Fig. 5. The measurement result and calculation result show good agreement. The comparison table with the antenna impedance bandwidth (IBW), the size with normalized wavelength and the index V_l of Ref. [5, 6, 7, 8, 9, 10, 11, 12, 13, 14] is shown in Table I. The cavity backed slot antenna is selected for comparison to our proposed antenna.

To evaluate the size of the antenna and impedance bandwidth (IBW), the formula of the performance index is defined as V_l as follows:

$$V_1 = w \times l \times h/\lambda_0^3 \quad (1)$$

where λ_0 is wavelength of lower frequency, w and l and h is the width, length and height of the antennas, respectively. As shown in Table I, our proposed antenna is relatively small. The frequency of IBW with VSWR < 2 of our proposed antenna is from 1.74 GHz to 2.10 GHz as shown in Fig. 5. In addition, the volume V_1 of conventional work in Ref. [8] and [14] is half of the V_1 of the our proposed antenna. However, the IBW of our proposed antenna is wider than that of conventional work of [8] and [14]. Therefore, our proposed antenna is wideband characteristics and compact as compared to related works.

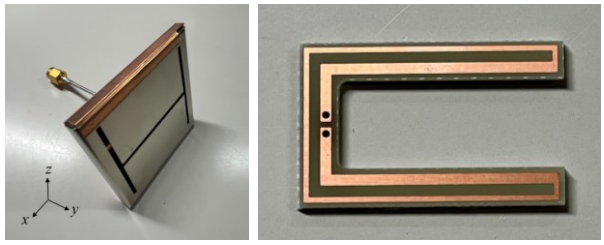

Fig. 3 Fig. 3 Photograph of proposed structure, (a) entire view, (b) top view of inner folded dipole antenna.

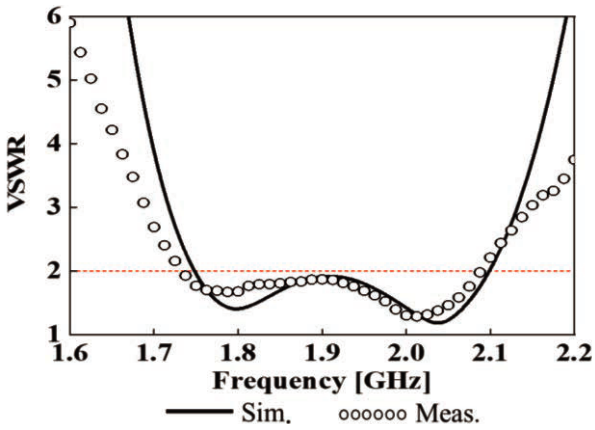

Fig. 4 Fig. 4 Comparison result of VSWR.

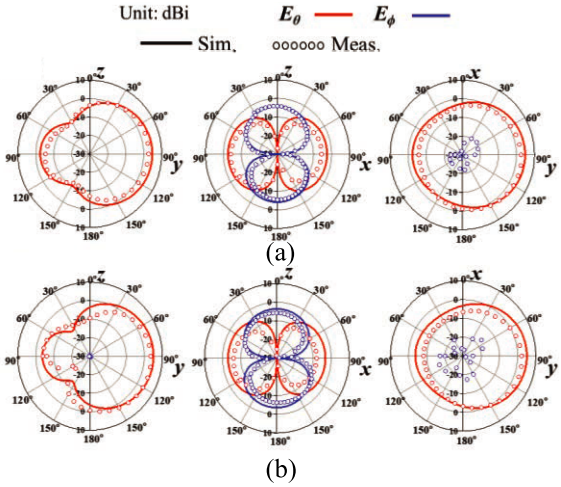

Fig. 5 Comparison of gain. (a) f = 1.79 GHz, (b) f = 2.03 GHz

Table I Comparison of related works and proposed antenna (PA)

Ref.	Frequency [GHz]		IBW	Size	V_l
	Min.	Max.	[%]	$w/\lambda_0 \times l/\lambda_0 \times h/\lambda_0$	
[5]	5.50	6.05	9.5	0.88 × 1.21 × 0.22	0.234
[6]	2.40	2.48	3.3	0.34 × 0.34 × 0.04	0.005
[7]	5.15	5.85	12.7	0.7 × 0.98 × 0.07	0.048
[8]	0.9	0.96	6.7	0.23 × 0.23 × 0.04	0.002
[9]	5.15	5.85	12.7	1.05 × 1.05 × 0.08	0.085
[10]	4.60	6.10	28.0	1.15 × 1.15 × 0.25	0.324
[11]	4.90	6.10	21.8	0.45 × 0.65 × 0.05	0.014
[12]	27.63	28.28	2.3	0.63 × 0.51 × 0.05	0.015
[13]	9.60	10.56	9.5	0.51 × 0.57 × 0.03	0.007
[14]	2.43	2.50	2.8	0.21 × 0.21 × 0.05	0.002
PA	1.74	2.10	15.9	0.35 × 0.35 × 0.03	0.004

4. Conclusion

This paper proposed miniaturization of backed cavity slot antenna. The folded dipole antenna was designed and employed for inner element to excite metal case with slot. The dimensions and antenna position were optimized for wideband. The relative bandwidth was 15.9% with the antenna size of $0.35\lambda_0$ times $0.35\lambda_0$ times $0.03\lambda_0$. The size of the antenna achieved compact size as compared to conventional studies. The proposed antenna was demonstrated by the measurement, and simulation results shows good agreement with measurement results. Further miniaturization and the proof of the metal robustness of the proposed antennas are considered as future work.

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