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A study on the Ground Plane Size for a Balanced-fed Dual-band Antenna Fabricated in a Multi-layer Dielectric Substrate

Yoshitaka Nakamura [1], Tadahiko Maeda [2]
Graduate School of Science and Engineering at Ritsumeikan University
1-1-1 Nojihigashi, Kusatsu-shi, Shiga, 525-8577 Japan
E-mail:[1] rs029004@ed.ritsumei.ac.jp,[2] tmaeda@is.ritsumei.ac.jp

1. Introduction

Recently, smart phones have received increasing attention and have become equipped with several high-speed wireless systems. A built-in antenna is often placed in proximity to the printed circuit board that has several metallic electrical parts and a ground plane. The radiation characteristics of a built-in antenna are influenced by the physical shape of the ground plane [1]- [3], and assessing the influence is important to maximize the performance of a mobile terminal. Thus, a balanced-fed dual-band antenna was proposed [4], [5] to reduce the undesired RF current along the ground plane and to contribute to stable operations [6].

The focus of this paper is to describe the effects of the ground plane size on the radiation characteristics of a shrink balanced-fed dual-band antenna embedded in a multi-layer dielectric substrate, which is designed to reduce the required size of both the antenna and the ground plane while maintaining the stable operation of the antenna system.

2. Antenna Structure

Fig.1 show the entire radiating element of the initial structure of the antenna studied in this paper. The proposed antenna has a unique 3-dimensional multi-layer configuration for the radiating element and vertical planar connections are arranged between multi layer sections of the radiating element to establish the dual-band operation at 2.4 GHz and 5 GHz frequency bands. The entire radiating element consists of the top, middle, and bottom section of the radiating element and is fed at the center of the bottom section of the radiating element as shown in Fig2-Fig.4. Table 1 summarizes other structural parameters for the initial radiating element. Assuming a conventional size of mobile terminal, the antenna is placed on a ground plane measuring 36.5 mm in width and 120 mm in length, and the bottom section of the radiating element is placed 1 mm above the ground plane as shown in Fig.5.

Fig.6 shows the geometry and configuration of the shrink structure of the antenna embedded in a dielectric substrate. The shrink antenna is designed to assess the feasibility of replacing the vertical planar connections with several parallel through-holes, which are common in printed circuit board production. The antenna parameters shown in Table 1 were optimized with the electrical constants (ϵ_r : 2.2 and tan δ : 0.00090) of the target substrate and the design results summarized in Table 2, where the dimensions of the ground plane were set to W=40 mm and H=50 mm. The results for the VSWR calculated by the FDTD (Finite Difference Time Domain) method for both initial and shrink structures are shown in Fig. 7 whereby an expanded bandwidth of 800 MHz is demonstrated with the proposed shrink structure.

3. The effects of a ground plane

The calculated results for several smaller sizes of ground plane are shown in Fig. 8 and Fig. 9. All results for the 5 GHz band show relatively stable VSWR characteristics. Also, when H is set at 30 mm, the results for the 2.4 GHz band still exhibit stable VSWR characteristics even with a small value of W, such as W=17.8 mm. However, as H becomes smaller than 20 mm, the antenna shows a higher VSWR in the 2.4 GHz band.

Because of the limited size of mobile terminals as well as other practical design limitations, the location where a built-in antenna is placed in a mobile terminal may not be selected freely. In this sense, if a built-in antenna still shows stable radiation characteristics even when the actual location of a built-in antenna is reallocated on the ground plane, then the built-in antenna offers practical flexibilities during the PC board design procedures. Fig. 10 shows three typical antenna locations to assess: 1) the allocation flexibility of the shrink antenna and 2) the effectiveness of the encircling rectangular slot. The encircling rectangular slot is introduced to isolate the antenna from the ground plane. The calculated VSWR results with and without the encircling slot are shown in Fig. 11 and Fig. 12 respectively. In short, it has been confirmed that the encircling rectangular slot exhibits stable VSWR characteristics in terms of antenna location on the ground plane.

4. Conclusion

A new shrink structure for a balanced-fed dual-band antenna fabricated in a multi-layered dielectric substrate was proposed to reduce the required size of both the antenna and the ground plane while maintaining the stable operation of the antenna system. Also, the effects of the physical size of the ground plane were evaluated and it was confirmed that the proposed shrink structure, combined with the newly introduced encircling rectangular slot, exhibits stable VSWR characteristics even when the antenna is reallocated on the ground plane.

Acknowledgments

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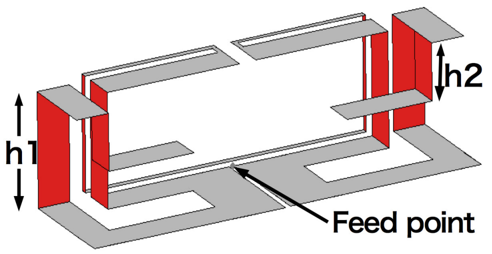

Figure 1 Antenna structure: Entire initial radiating element with vertical planar connections.

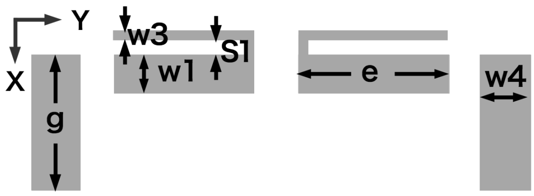

Figure 2 Antenna structure: Top section of radiating element.

Figure 3 Antenna structure: Middle section of radiating element.

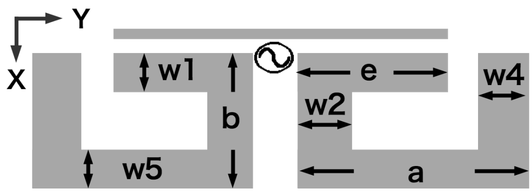

Figure 4 Antenna structure: Bottom section of radiating element.

Table 1 Antenna parameters : Initial structure.

a : 18mm	b : 10mm	c : 12.25mm
e : 13mm	f : 8mm	g : 7mm
h1 : 8mm	h2 : 4mm	s1 : 1mm
w1 : 3mm	w2 : 5mm	w3 : 1mm
w4 : 3mm	w5 : 3mm	w6 : 3mm

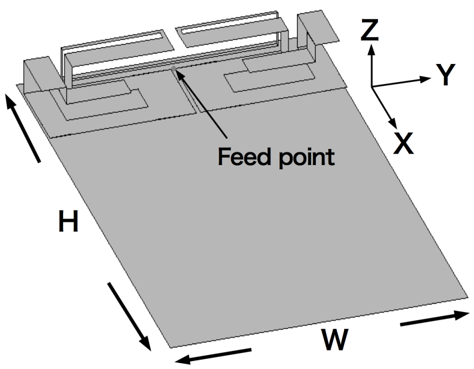

Figure 5 Antenna structure with planar connections: Placed on a ground plane.

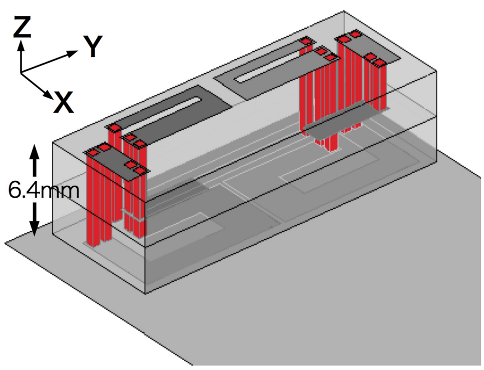

Figure 6 Antenna structure with through-hole connections.

Table 2 Antenna parameters : shrink structure.

a : 16.6mm	b : 9.6mm	c : 10.4mm
e : 10.8mm	f : 6.4mm	g : 6.8mm
h1 : 6.4mm	h2 : 3.2mm	s1 : 0.8mm
w1 : 1.2mm	w2 : 1.6mm	w3 : 1.2mm
w4 : 2.4mm	w5 : 3.2mm	w6 : 1.2mm

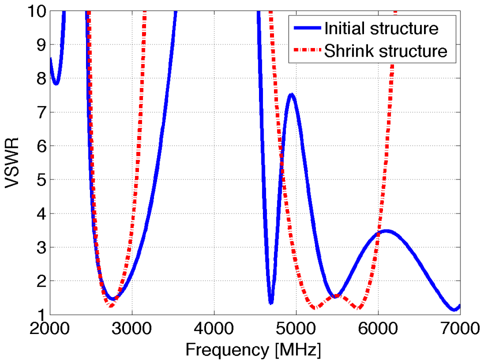

Figure 7 Calculated results of VSWR for initial structure vs. shrink structure.

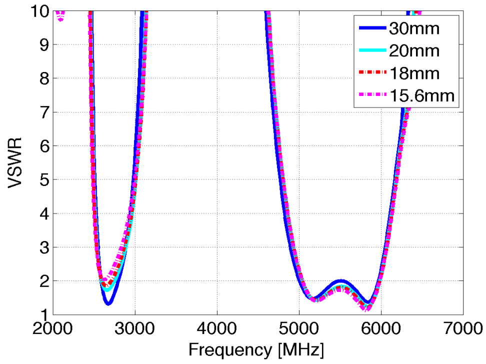

Figure 8 VSWR as a parameter of W. (H = 30mm)

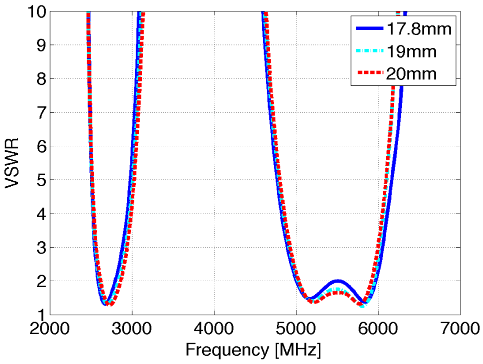

Figure 9 VSWR as a parameter of H. (W = 35.6mm)

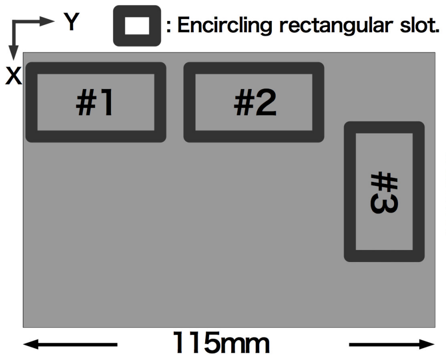

Figure 10 Antenna locations on a ground plane.

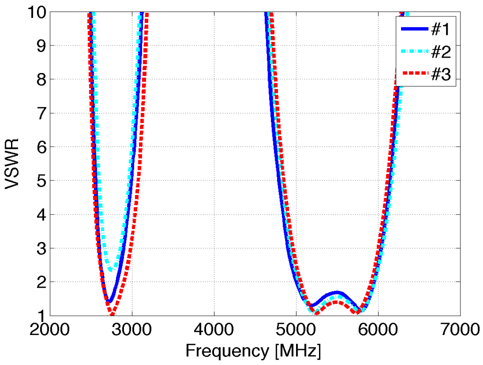

Figure 11 VSWR of the proposed antenna without a rectangular slot.

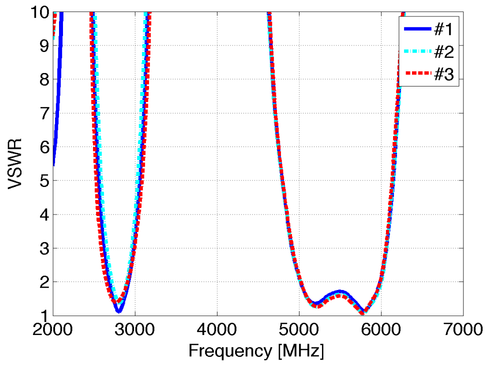

Figure 12 VSWR of the proposed antenna with a rectangular slot.