

# Stub-loaded Dual-polarized Small MSA with Grounded conductors

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## 1. Introduction

Microstrip patch antennas (MSAs) are used in various applications because of their attractive properties such as low profile, light weight, and easy fabrication. Since the miniaturization of antennas is necessary for wireless systems, several methods to miniaturize MSAs have been proposed, such as shorted-MSAs (quarter-wave MSAs) [1] and making a slit on the patch conductor [2]. However, these methods cannot be applied to dual-polarized MSAs.

In this paper, a dual-polarized MSA miniaturized by bending the patch conductor and placing grounded conductors on the ground plane is presented. Matching stubs are incorporated in the patch conductor to improve its impedance bandwidth. The calculation results shown in this paper are obtained by a standard finite-difference time-domain (FDTD) method.

## 2. Capacitance-loaded MSA

### 2.1 Antenna configuration

Figure 1 shows the geometry of the proposed antenna. Two grounded conductors with a width of  $W_g$  and a height of  $h_g$  are placed on the ground plane. Each edge of the patch conductor is bent to face the grounded conductors. The vertical length of the patch conductor is  $h_b$ , and the length of the region in which the grounded conductor and the vertical part of the patch conductor overlap is  $h_o$ . The other dimensions of the antenna are shown in Fig. 1.  $\lambda_c$  denotes the center wavelength of the frequency band of interest.

### 2.2 Effect of grounded conductors

Figure 2 shows the relationship between the ratio of miniaturization and  $h_b$  and between the relative bandwidth (RBW) for  $VSWR < 2$  and  $h_b$ . In the figure,  $W_g$  is constant at 50 mm. The resonant frequency is normalized by the resonant frequency at  $h_b = h_g = 0$  [mm],  $f_{\text{normal}}$ . This can be put into the ratio of miniaturization of the antenna to the normal MSA,  $M$ . The value  $M$  decreases with an increase in the area of the region where the conductors overlap. In addition, the relative bandwidth decreases with an increase in  $h_b$  when the value of  $h_o$  is constant. In order to clarify these relations, the index  $\alpha$  is used:

$$\alpha = RBW / f_0 \quad (1)$$

where  $f_0$  is the resonant frequency of the antenna. The value  $\alpha$  increases with the RBW; it also increases with a decrease in  $f_0$ . Figure 3 shows the relationship between  $\alpha$  and  $h_b$  for various  $h_o$  values. In order to make  $\alpha$  as large as possible, it is necessary to make  $h_g$  as large as possible and to decrease  $h_b$  gradually until the desired resonant frequency is attained.

Figure 4 shows the relationship between  $M$  and  $h_b$  when  $h_g$  is equal to  $h$ . The RBW at each point is also shown in the figure. According to the plot in Fig. 4, we choose  $w_g = 0.257\lambda_c$  and  $h_b = 0.006\lambda_c$  as the optimum values in the case of  $M < 0.63$ . The relative bandwidth is 3.8% in this case.

### 2.3 Dual-polarized operation

Let us consider applying the structure of the proposed antenna to a dual-polarized MSA. In the simplest construction, the patch conductor is bent at all the four sides and the grounded conductors are placed in such a manner so as to face the sides, as shown in Fig. 5. However, the resonant frequency of the antenna shown in Fig. 5 shifts to a higher frequency than that of the single-polarized

type mentioned in the previous section. Figure 6 shows the relationship between the resonant frequency and the relative bandwidth when the value of  $h_b$  is varied. The resonant frequency of the dual-polarized MSA is approximately 1.3 times that of the single-polarized one; this value is obtained by a comparison of the same relative bandwidth for the two antennas. If we consider the MSA to be a transmission line, this frequency shift can be considered to be caused by a decrease in the characteristic impedance of the transmission line.

In order to lower the resonant frequency, the center of each edge of the patch conductor is notched, as shown in Fig. 7. The grounded conductors on the ground plane face the vertical part of the patch conductor, except for the notched part. When the length and width of the notch,  $L_n$  and  $W_n$ , are  $0.086\lambda_c$  and  $0.006\lambda_c$ , respectively, the resonant frequency is less by 14% when compared with the value when the notches are absent, as shown in Fig. 8. This resonant frequency corresponds to a miniaturization of 38% ( $M = 0.62$ ) with 2.7% of the relative bandwidth.

### 3. Broadening impedance bandwidth by matching stubs

As a technique to improve the impedance bandwidth, the use of a matching structure with two stubs on the patch conductor has been reported [3]. We attempt to apply this technique to the dual-polarized MSA. Figure 9 shows the geometry of the stub-incorporated dual-polarized MSA. The shorted stub of each port is folded in order to avoid physical interference. The total length of the shorted stub is  $0.237\lambda_c$ , and the length of the open stub is  $0.043\lambda_c$ . The other dimensions are shown in Fig. 9. Figure 10 shows a comparison of the frequency characteristics of the return loss for the proposed antenna with/without matching stubs. The inductance of the probe is numerically subtracted in the case where stubs are absent. The relative bandwidth for  $VSWR < 2$  is 2.7% without stubs. On the other hand, a relative bandwidth of 6.0% is obtained by incorporating stubs. Thus, the relative bandwidth is approximately 2.2 times that of the MSA without stubs.

Figure 11 shows the radiation patterns at the center frequency when the x-port is excited. Beam asymmetry in the E-plane is observed for the antenna without stubs. This asymmetry is mainly caused by the radiation from the probe. On the other hand, the symmetry of the radiation pattern is improved for the antenna with stubs. It is considered that the radiation from the feeding probe and that from the shorting conductor that is connecting the shorted stub to the patch conductor interfere with each other since the shorting conductor is located near the feeding probe. It is observed that the folded stubs do not degrade the quality of the radiation pattern in this calculation result.

### 4. Conclusion

We have proposed a novel dual-polarized MSA with grounded conductors that has a size smaller than that of the conventional MSA. It has been confirmed that a miniaturization of 38% can be realized by using the grounded conductors and notching the patch conductor. We have also demonstrated the improvement of its bandwidth by employing matching stubs on the patch conductor for dual-polarized operation. We have shown that the relative bandwidth of the proposed antenna is approximately 2.2 times that of the MSA without stubs through numerical calculations.

### References

- [1] J. R. James and P. S. Hall (Eds.), *Handbook of Microstrip Antennas*, Peter Peregrinus, London, UK, pp.306–308, 1989.
- [2] G. Kossiavas and M. Sauvan, “The C-Patch: A Small Microstrip Element,” *Electron. Lett.*, vol.25, No.4, pp.253–254, Feb. 1989.
- [3] T. Yanagi, Y. Nishioka, M. Ohtsuka, S. Makino, “Basic Study on Wideband Microstrip Patch Antenna Incorporating Matching-Stubs onto Patch Conductor,” *IEEE AP-S Int. Symp. Dig.*, Hawaii, pp.885–888, June 2007.

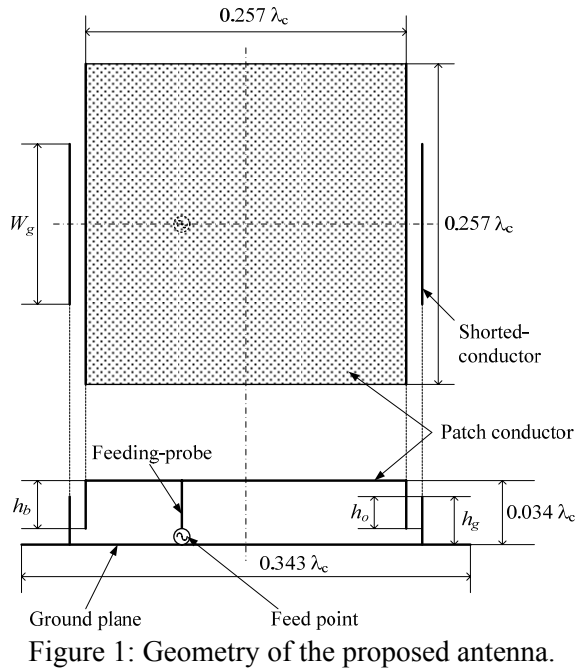


Figure 1: Geometry of the proposed antenna.

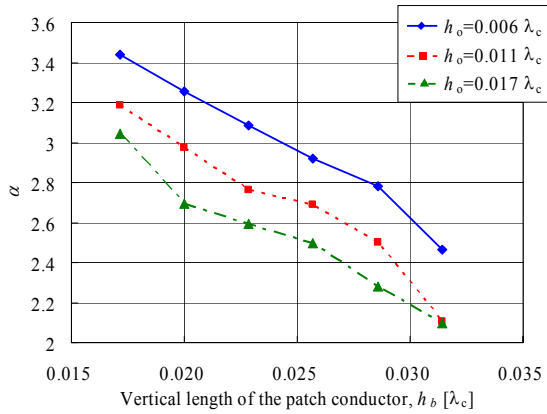


Figure 3: Plot of  $\alpha$  vs.  $h_b$ .

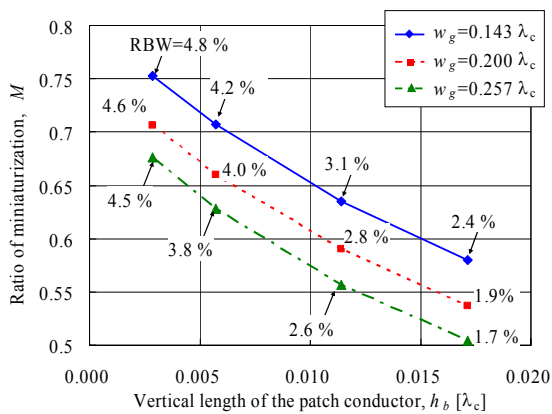
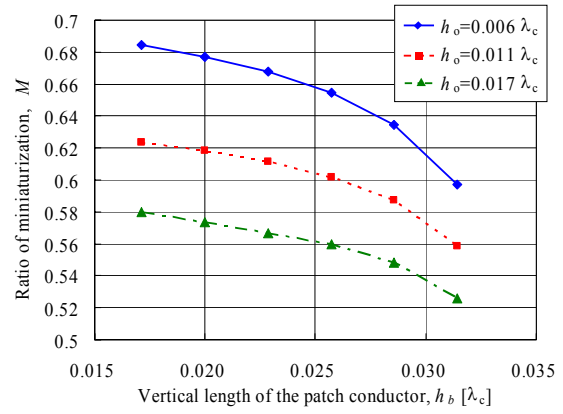
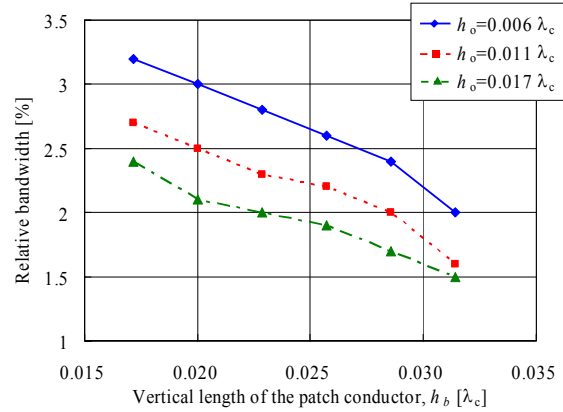


Figure 4: Ratio of miniaturization vs.  $h_b$ . ( $h_g = h = 0.034 \lambda_c$ )



(a)



(b)

Figure 2: Relationships between (a) ratio of miniaturization and  $h_b$  and (b) relative bandwidth and  $h_b$  ( $W_g = 0.143 \lambda$ ).

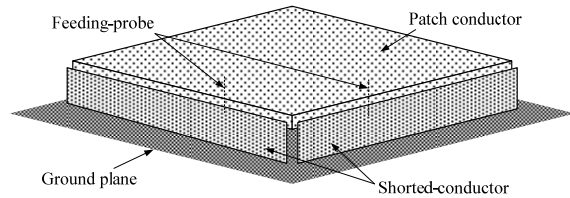


Figure 5: Dual-polarized capacitance-loaded MSA.

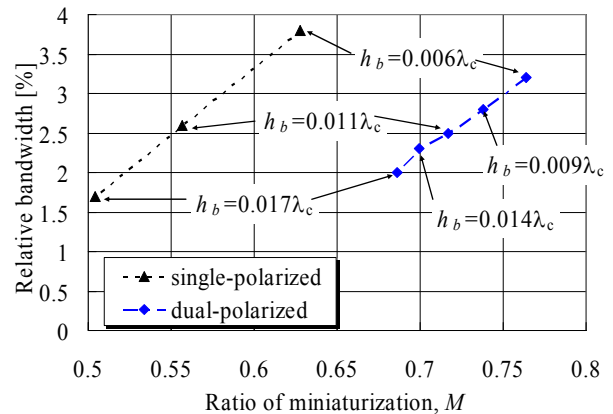


Figure 6: Relationship between the ratio of miniaturization and the relative bandwidth for single-/dual-polarized operation.

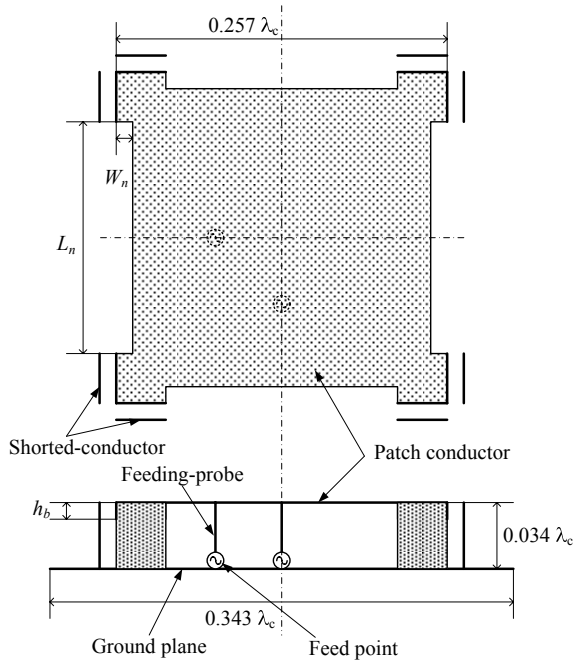


Figure 7: Dual-polarized capacitance-loaded MSA with notched edges.

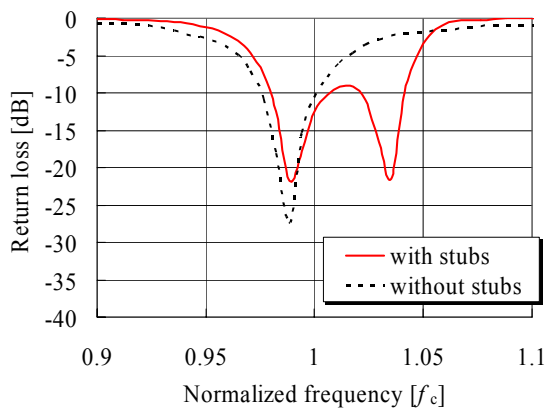


Figure 10: Frequency characteristics of return loss with/without matching stubs.

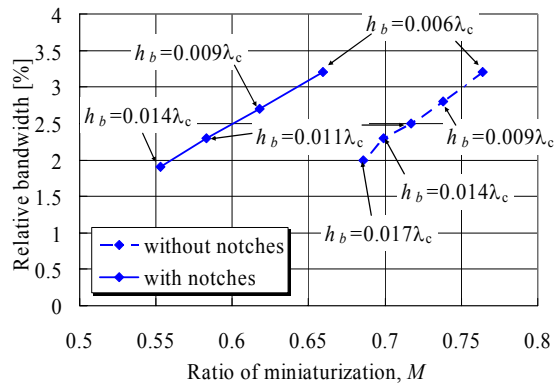


Figure 8: Relationship between the resonant frequency and the relative bandwidth with/without notches. ( $L_n = 0.086\lambda_c$ ,  $W_s = 0.006\lambda_c$ )

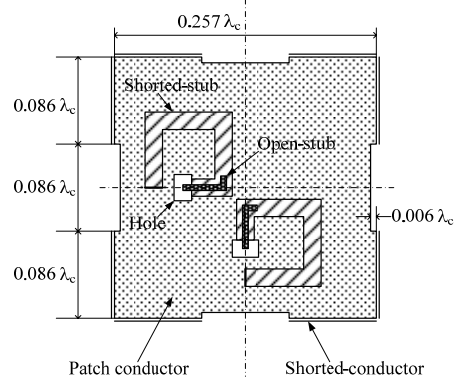
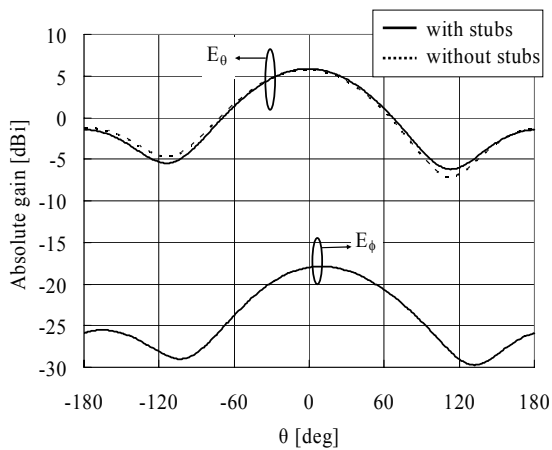
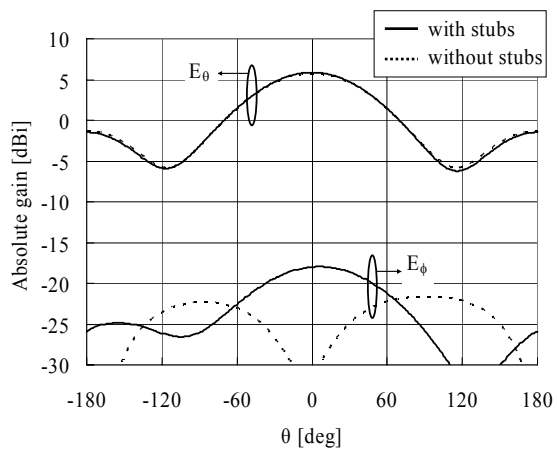


Figure 9: Dual-polarized capacitance-loaded MSA with matching stubs.



(a) E-plane (x-z plane)



(b) H-plane (y-z plane)

Figure 11: Radiation pattern at the center frequency  $f_c$ .