Wideband and Dual–band Stacked Square Microstrip Antennas with Shorting Plates and Slits

Takafumi Fujimoto [1]
[1] Graduate School of Science and Technology, Nagasaki University
1-14 Bunkyo-machi, Nagasaki-shi, 852-8521, Japan, takafumi@nagasaki-u.ac.jp

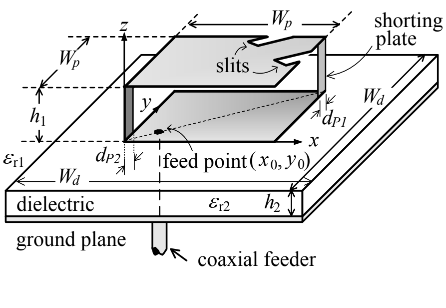
1. Introduction

Author has been proposed a wideband stacked square microstrip antenna (MSA) with shorting plates [1]. By shorting the upper patch to the lower patch at two apexes of the diagonal of the square patch, the bandwidth of the vswr $\leqq 2$ has been achieved in the frequency range between the first and the third resonant frequencies and the gain at θ=0° around the second resonant frequency has been improved.

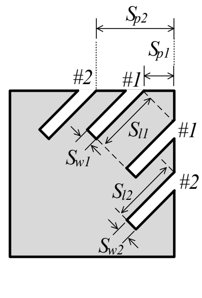
In this paper, the improvement of the gain in the vicinity of the third resonant frequency is achieved by inserting slits on the upper patch and by changing the width of the shorting plates. Moreover, the vswr and gain of the antenna with slits on the lower patch are also discussed. The simulated results show that the antenna with slits on the lower patch has the similar gains around the first and second resonant frequencies. The antenna with slits on the lower patch is useful as a dual–band antenna which radiates at the same direction at two operational frequencies.

2. Antenna Design

Figures 1(a) shows a stacked square MSA with shorting plates and slits and Fig. 1(b) shows geometry of the slits. The antenna consists of a dielectric substrate and a layer of air with a square patch. The upper and lower patches are the same size and their width is W_P=14mm. The upper patch is shorted to the lower patch at two apexes on the diagonal of the square patch by conducting plates. The widths of the shorting plates are d_{P1} and d_{P2}. The slits are inserted at the location of the line symmetry for diagonal on the upper or the lower square patch. The dimension of the $\#n$ $(n = 1, 2, 3)$ slit is $S_{wn} \times S_{ln}$ and the location of the $\#n$ slit is S_{pn}. Figure 1(a) shows the case of the upper patch with the one pair of the slits. The relative dielectric constant and the thickness of the upper and lower layers are ε_{r1}=1.0, h_1 and ε_{r2} =2.6, h_2=2.4mm, respectively. The width of the dielectric substrate is W_d=100.0mm. The antenna is excited at the lower patch by a coaxial feed through the lower dielectric substrate at point x_0, y_0 which lays on the diagonal.



(a) perspective view



(b) dimension of slits (the case of n=2)

Figure 1: Geometry of stacked square microstrip antenna with shorting plates and slits.

3. Results and Discussion

In the calculations in this paper, the simulation software package FIDELITY, based on the finite difference time domain method [2] is used.

Figure 2 shows the calculated input impedance of the stacked square MSA with shorting plates and without slits [1]. There are three peaks in the range from 4GHz to 12GHz. In this paper, the peaks of the input resistance are defined as the resonant frequency.

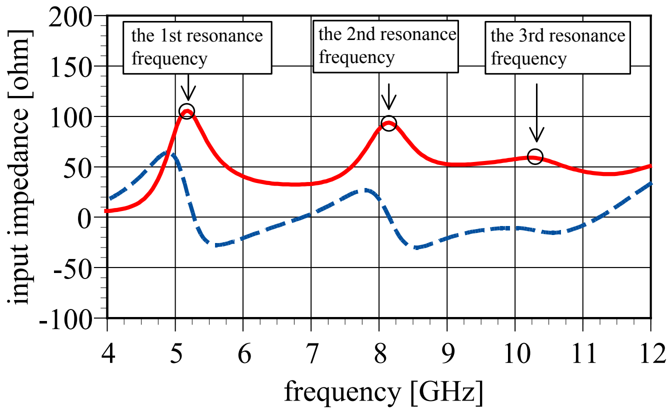
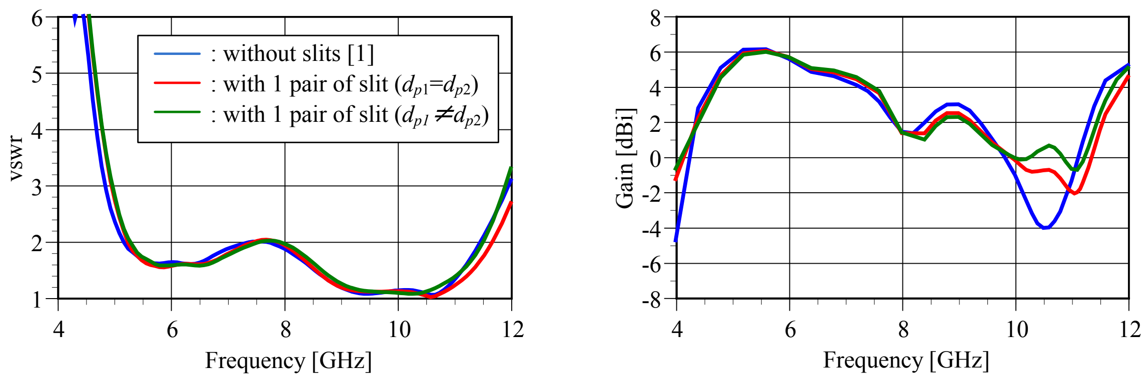


Figure 2: Input impedance of stacked MSAs with shorting plates and without slits (h_1=10.0mm, d_{P1}=d_{P2}=2.0mm, x_0=y_0=-3.6mm)

3.1 Antenna with slits on the upper patch (Wideband antenna)

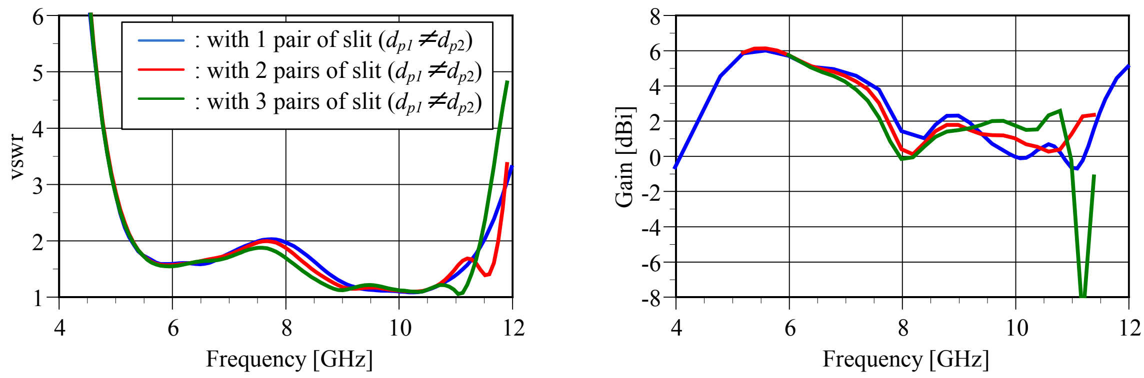
Figure 3 (a) and (b) show the vswr and the gain at θ=0° of the stacked MSA with the one pair of the slits on the upper patch for changes of the width of the one shorting plate d_{p2}. Those of the stacked square MSA without slits and with the shorting plates d_{p1}=d_{p2}=2.0mm [1] are also shown for comparison. The locations of the feed point are adjusted so that the best performance of the vswr is obtained in each antenna. It can be confirmed that the vswr hardly changes when the slits are inserted on the upper patch. In the case of $d_{p1} \neq d_{p2}$, although the gain around the second resonant frequency decreases slightly, the gain is improved around the third resonant frequency (from 10.0GHz–11.0GHz).

Figure 4 shows the vswr and the gain at θ=0° of the stacked MSA with the slits on the upper patch for changes of the number of the pairs of the slits. The dimensions of all slits are same. The widths of the shorting plats d_{p1} and d_{p2} are 2.0mm and 0.8mm, respectively. The slits do not influence the vswr. As the number of the slits increase, the gain around the second



(a) vswr (b) gain

Figure 3: Characteristics for changes of the width of the shorting plates (h_1=10.0mm)



(a) vswr (b) gain

Figure 4: Characteristics for changes of the numbers of pair of the slits (h_1=10.0mm, d_{p1}=2.0mm, d_{p2}=0.8mm)

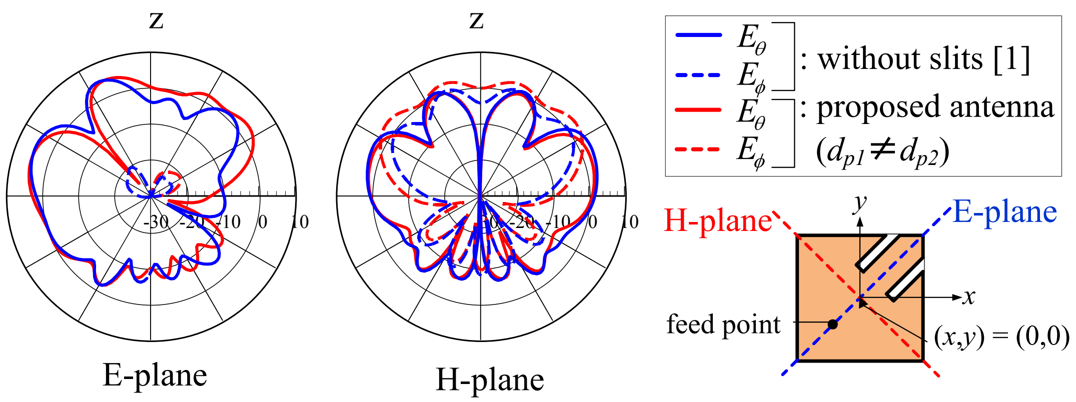


Figure 5: Radiation patterns at 10.6GHz (around the third resonant frequency) of the antenna with the two pairs of the slits (h_1=10.0mm, d_{p1}=2.0mm, d_{p2}=0.8mm)

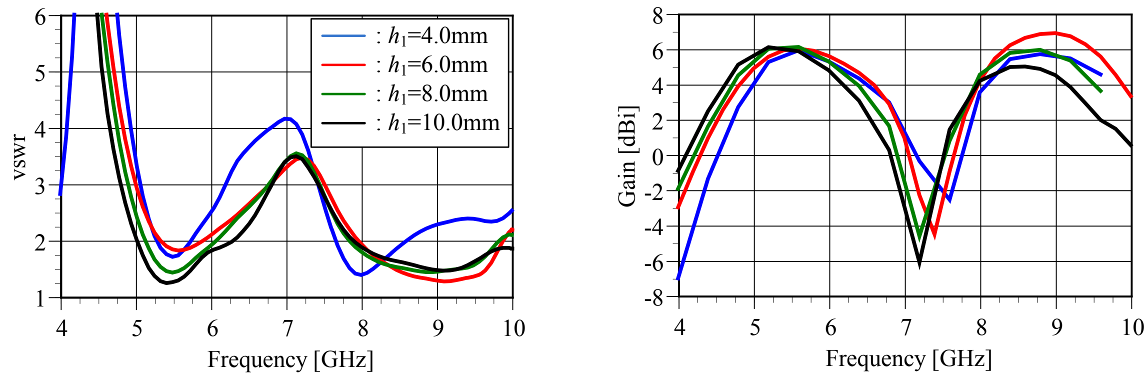
resonant frequency decreases and the gain around the third resonant frequency increases. In the antenna with two pairs of the slits, the gain at $\theta = 0°$ is greater than 0 dBi in the frequency range between the first resonant and third frequencies.

Figure 5 shows the calculated radiation pattern of the antenna with two pairs of the slits at 10.6GHz. Figure 5 also shows the radiation pattern of the antenna without the slits in the reference [1] for comparison. E and H–planes are shown for ϕ=45° and 135°, respectively. It can be confirmed that the gain at θ=0° is improved at 10.6GHz by inserting the slits on the upper patch and changing the width of the shorting plates.

3.2 Antenna with slits on the lower patch (Dual–band antenna)

Figure 6 (a) and (b) show the vswr and the gain at θ=0° of the stacked MSA with the slits on the lower patch for changes of the thickness h_1. The widths of the shorting plate of all antennas are d_{p1}=d_{p2}=2.0mm. The location of the feed point is adjusted so that the bandwidth of vswr $\leqq$ 2 around the first and the second resonances becomes as wide as possible. Although the vswr and the gain at $\theta = 0°$ between the first and the second resonant frequencies decline by inserting the slits on the lower patch, the gain at $\theta = 0°$ is vastly improved. When the thickness h_1 is 8.0mm, the gain around the second resonance is similar to that around the first resonance. Those gains are approximately 6.0dBi.

Figure 7 shows the radiation patterns at the first and second resonant frequencies. The thickness of the shorting plates h_1 is 8.0mm. Although the conventional stacked MSA radiates



(a) VSWR (b) directivity

Figure 6: Comparison of stacked MSAs with and without slits plates ($d_{p1} = d_{p2}$=2.0mm)

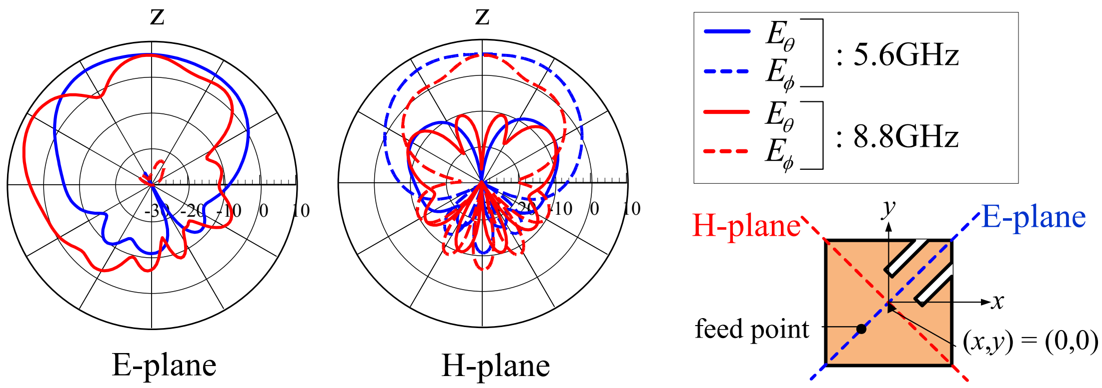


Figure 7: Radiation patterns around the first and second resonant frequencies (d_{p1} = d_{p2}=2.0mm, h_1=8.0mm)

the low elevation angles at the second resonant frequency, the antenna with the slits on the lower patch has the radiation peak at high elevation angles at the second resonant frequency, which is same as the radiation patterns at the first one.

4. Conclusion

A wideband stacked square MSA with shorting plates and slits on the upper patch has been proposed. The vswr $\leqq$ 2.0 with gain at θ=0° $\geqq$ 0 dBi has been achieved in the frequency range between the first and third resonant frequencies.

Moreover, a dual–band stacked square MSA with shorting plates and slits on the lower patch has been proposed. The antenna with the slits on the lower patch has similar gain at θ=0° at the first and second resonant frequencies. The antenna is useful as a dual band antenna.

References

[1] T. Fujimoto, "Wideband stacked square microstrip antenna with shorting plates", IEICE Trans. COMMUN. Vol. E91-B, No.5, pp.1669-1672, May 2008.

[2] Zeland Software, Fidelity User's Manual, April 2000.