LETTER

Wideband Stacked Square Microstrip Antenna with Shorting Plates

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SUMMARY A stacked square microstrip antenna with shorting plates is proposed for wide band operation. The vswr ≦ 2 with gain at θ=0° ≧ 0 dBi is achieved in the frequency range between the first and second resonant frequencies by loading the two shorting plates. The proposed antenna has bandwidth of approximately 60%.

key words: *stacked microstrip antenna, shorting plates, wide bandwidth, vswr, gain*

1. Introduction

The impedance bandwidth of a probe-fed microstrip antenna (MSA) is inherently narrow. Therefore, many approaches to increase the bandwidth such as using additional microstrip resonators [1], stacking parasitic patches above a fed patch (stacked MSA) [2] and embedding a U-shaped slot in the radiating patch [3], etc. have been proposed. It is desirable for wideband antennas that the frequency characteristic of the vswr be wide and the direction of the radiation peaks is the same in the frequency range.

The structure of the stacked MSA is relatively simple because it can be realized by just stacking a parasitic patch, whose geometry is the same as the fed patch, above the fed patch. In the conventional half wavelength stacked MSA, although the radiation peak in the first mode is at high elevation angles, that in the second mode is at low elevation angles [4]. Therefore, the bandwidth of the stacked MSA is only enhanced in the frequency band of the first mode.

In this letter, a wideband stacked square MSA with two shorting plates is proposed. The proposed antenna has good impedance matching and radiates at high elevation angles in the frequency range between the first and second resonant modes. Some wideband stacked MSAs with shorting pins or plates have been proposed [5], [6]. However, although the antenna sizes are compact, the bandwidths (20–30%) are a half or less than of the antenna presented here.

In the calculations in this letter, the simulation software package FIDELITY 3.53, based on the finite difference time domain method is used [7]. In order to ascertain the accuracy of the calculated results, the calculated vswr and gain are compared with experimental data.

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2. Antenna Design

Figure 1 shows a stacked square MSA with two shorting plates. The antenna consists of a dielectric substrate and an air layer with a square patch. The upper and lower square patches are the same size and have a width W_p=14.0 mm. The upper patch is shorted to the lower patch at two apexes on the diagonal of the square patch by conducting plates. The width of the shorting plates is d_p=2.0 mm. The relative dielectric constant and the thickness of the upper and lower layers are ε_{r1}=1.0, h_1=10.0 mm and ε_{r2}=2.6, h_2=2.4 mm, respectively. The width of the dielectric substrate is W_d=100.0 mm. 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.

3. Results and Discussion

Figure 2 shows the calculated input impedance of two stacked square MSAs, one with and one without the shorting plates. The locations of the feed point of the antennas are adjusted so that the best vswr performance is obtained for each antenna (as shown in Fig. 3). In both the antennas, there are three peaks in the range from 4 GHz to 12 GHz. In this letter, the peaks of the input resistance are defined as the resonant frequency.

Figures 3(a) and (b) show the calculated vswr and gain at θ=0° of the stacked square MSAs with and without the shorting plates, respectively. In the stacked MSA without the shorting plates, the vswr ≦ 2 is only around the first resonant frequency. However, the bandwidth of the vswr ≦ 2 is extended in the frequency range between the first and third

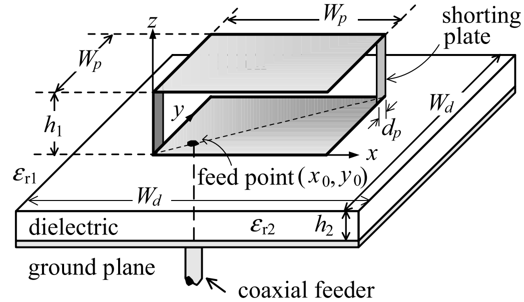


Fig. 1 Geometry of stacked square microstrip antenna with shorting plates and its coordinate system.

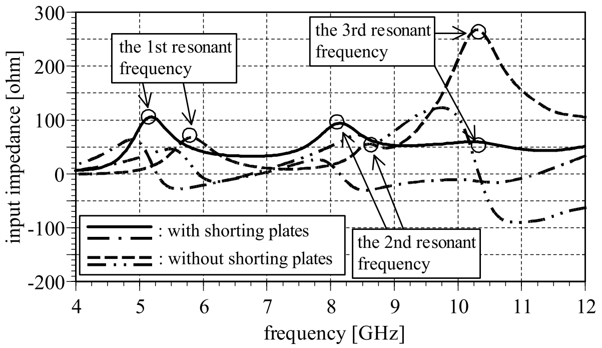


Fig. 2 Calculated input impedances (with shorting plates: $x_0 = y_0 = 3.4$ mm, without shorting plates: $x_0 = y_0 = 5.0$ mm).

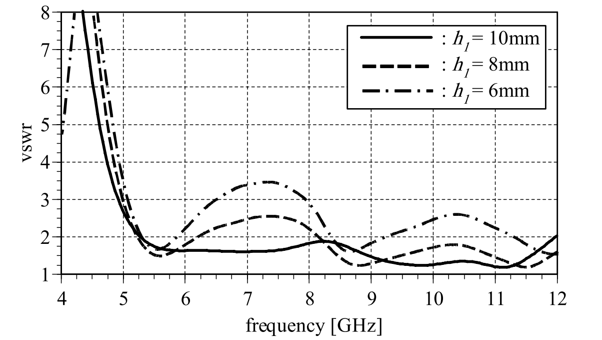


Fig. 4 Calculated vswrs for changes of h_1 (h_1 = 6.0 mm: $x_0 = y_0 = 4.2$ mm, h_1 = 8.0 mm: $x_0 = y_0 = 3.9$ mm, h_1 = 10.0 mm: $x_0 = y_0 = 3.4$ mm).

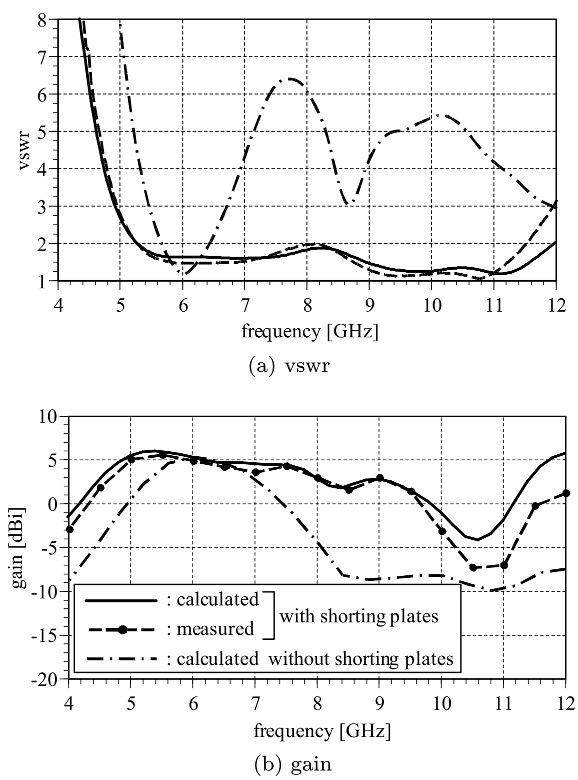


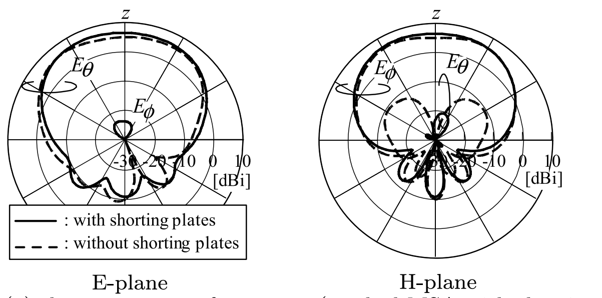
Fig. 3 Vswrs and gains at $\theta = 0°$ of stacked MSAs with and without shorting plates (with shorting plates:$x_0 = y_0 = 3.4$ mm, without shorting plates:$x_0 = y_0 = 5.0$ mm).

resonant modes by loading the shorting plates. The gain of the antenna with the shorting plates increases significantly in the frequency range around the second mode compared with that without the shorting plates. The calculated bandwidth of vswr $\leqq 2$ with gain $\geqq 0$ dBi of the stacked MSA with the shorting plates is 60.2% (5.28–9.83 GHz), which is approximately 5.5 times of that without the shorting plates. Figures 3(a) and (b) also show the measured results for the stacked MSA with the shorting plates. The antenna was made of copper-clad Glass-fiber-PTFE. The calculated results agree well with the measured ones. The measured bandwidth is 59.1% (5.26–9.67 GHz). In this letter, the vswr and gain aren't presented for change of the width of the shorting plates d_p. However, when the width d_p changed from 1.6 mm to 2.8 mm, the differences of the calculated vswr and gain weren't observed in the frequency range between the first and second resonant frequencies.

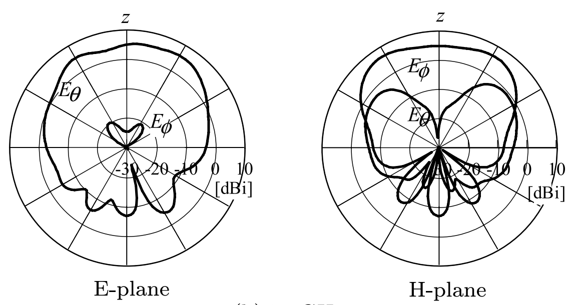
Figure 4 show the vswr of the stacked MSA with the shorting plates for changes of the thickness h_1. The location of the feed point is adjusted so that the vswrs around both the first and second resonant frequencies are less than 2 and the vswr in the frequency range between the first and second resonant frequencies becomes as small as possible. As the thickness h_1 increases, the vswr is improved over a wide frequency range spanning from the first to second resonant frequency. Since the electric currents flow on between the patches and the shorting plates, the resonant frequencies depend on the total length of the diagonal of the square patches and the shorting plates. Therefore, impedance tuning is possible over a wide frequency range by changing the thickness h_1 and the feed point.

Figures 5(a)–(d) show the calculated directivities of the stacked square MSA with the shorting plates from 5.2 GHz to 9.2 GHz, which is the frequency range where the calculated gains agree well with the measured results. Figure 5 also show the calculated directivities of the stacked square MSA without the shorting plates at the first and second resonant frequencies for comparison. E and H–planes are shown for ϕ=45° and 135°, respectively. At the first resonant frequency, the radiation patterns of the stacked MSA with the shorting plates are nearly the same as those without the shorting plates. However, differences are observed at the second resonant frequency. In the case without the shorting plates, a null exists at around θ=0° [4] at the second resonant frequency. The null moves from θ=0° to around θ=30° by loading the shorting plates. Therefore, the gain at θ=0° of the stacked MSA with the shorting plates increases.

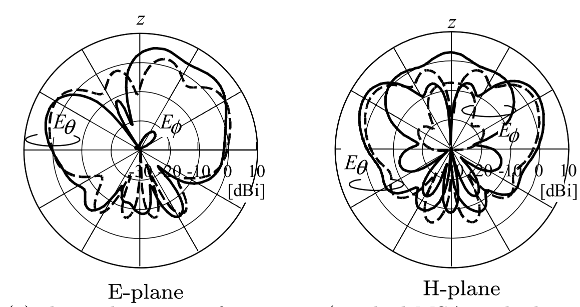
Figures 6 and 7 show the calculated magnetic fields of the stacked MSAs with and without the shorting plates, respectively, at the second resonant frequency, when the differences in the directivity are largest. The magnetic fields on the patches and the shorting plates correspond to the electric currents. In the stacked MSA without the shorting plates, the intensities of the magnetic field around the center on the upper and lower patches are approximately zero. In the



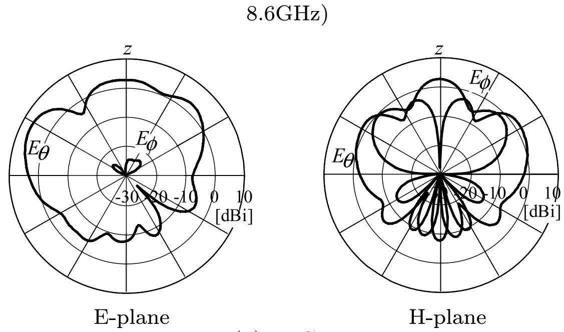
(a) the 1st resonant frequency. (stacked MSA with shorting plates : 5.2GHz, stacked MSA without shorting plates : 5.6GHz)



(b) 7.2GHz.



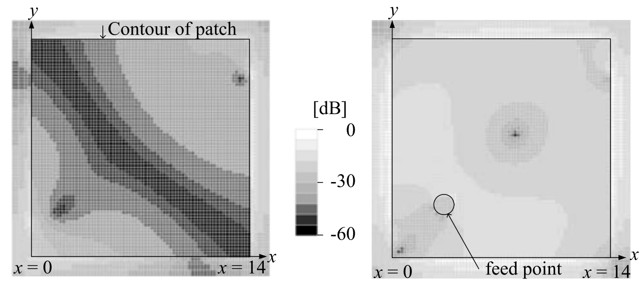
(c) the 2nd resonant frequency. (stacked MSA with shorting plates : 8.2GHz, stacked MSA without shorting plates : 8.6GHz)



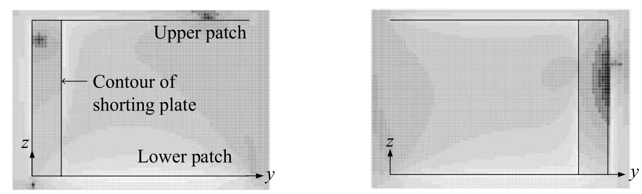
(d) 9.2GHz.

Fig. 5 Calculated directivities (with shorting plates: $x_0 = y_0 = 3.4$ mm, without shorting plates: $x_0 = y_0 = 5.0$ mm).

stacked MSA with the shorting plates, however, the null of the magnetic field on the lower patch shifts from the center of the square patch. Moreover, the null that appears on the shorting plates has a different location and area for each plate. The fact that the magnetic field (the electric current) distributions are not symmetric to the diagonal at ϕ=135° of the patches causes the shift of the null point in the radiation pattern at the second resonant frequency mentioned above.

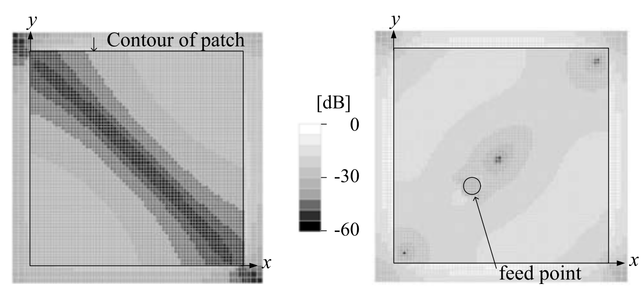


(a) Upper patch. (b) Lower patch.



(c) Shorting plate. (x=0mm) (d) Shorting plate. (x=14mm)

Fig. 6 Magnetic fields of stacked MSA with shorting plates at the second resonant frequency ($x_0 = y_0 = 3.4$ mm).



(a) Upper patch. (b) Lower patch.

Fig. 7 Magnetic fields of stacked MSA without shorting plates at the second resonant frequency ($x_0 = y_0 = 5.0$ mm).

4. Conclusion

A stacked square MSA with shorting plates has been proposed for wideband operation. A vswr ≦ 2 with gain ≧ 0 dBi at θ=0° has been achieved in the frequency range between the first and second resonant frequencies by loading the two shorting plates at the edges of the square patches. Moreover, the operational principles of the antenna were discussed. The vswr and gain were calculated by simulation software and compared with measured results. The good agreement between the calculations and measurements confirm the results of this work.

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