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UNIPLANAR SINGLE CORNER-FED DUAL-BAND DUAL-POLARIZATION PATCH ANTENNA ARRAY

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Abstract—A uniplanar corner-fed patch antenna is presented with single-point microstrip feed and single layer substrate. Two orthogonal polarized dominant modes TM_{010} and TM_{001} are excited at two different frequencies. By utilizing a corner-fed structure, impedance matching for two bands can be adjusted much independently and the small ratio between two operating frequencies is easy to achieve. In addition, this simple and compact structure makes the patch antenna very convenient to form an array. A patch antenna operating at 12.5 GHz and 14.25 GHz with two linear orthogonal polarizations has been designed. The frequency ratio is only 1.14. The return loss, current distribution and radiation patterns of the patch element are investigated in detail. An 8 by 8 array has been developed, of which gains more than 23.4 dBi have been obtained at dual frequencies. Measured results agree well with simulated ones, which validate the proposed structure.

1. INTRODUCTION

For satellite communication systems, antennas operate at two separate transmit-receive bands, preferably with dual polarization capability. Microstrip antennas have become a favorite choice of antenna engineers owing to their attractive features of low profile and light weight; moreover, they can produce two different operating frequency bands on a single radiating patch, which can offer a potentially compact design for dual-frequency antennas [1]. Various polarization combinations are generated at two operating frequencies such as identical linear polarization (LP), dual linear polarizations, identical circular polarization (CP), different polarization types (LP and CP),

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or dual orthogonal circular polarizations [1–5]. However, the simplest way to operate at dual frequencies is to use the first resonance of the two orthogonal dimensions of a rectangular patch, i.e., the TM_{010} and the TM_{001} dominate modes. Probe-fed or slot coupling fed structure are commonly used in orthogonal-mode dual-band patch antennas to implement good matching over dual-band [3–6]. The former is easier to design and more suitable for thick substrates, providing wider bandwidths. However, it is more difficult to form an array. The latter eliminates vertical connection and soldering, resulting in easier implementations in large arrays, but is is costly, more complex to design and complicate to fabricate.

Single layer corner-fed microstrip antenna array for dual-polarization operation has been developed [7]. In that paper, two-port excitation is used. In a more recent paper, a single-fed microstrip patch antenna element has been proposed to realize dual-band dual-polarization operations and small ratio between two operating frequencies [8]. In this paper, as an alternative to [8], we utilize the structure of insertion corner-fed to make the surface currents concentrate at the central part of the patch, so that impedance matching for two bands can be adjusted much independently by varying the location of feeding point. Consequently, the small ratio between two operating frequencies is easy to achieve and the gains for two frequencies are more than 2.5 dBi higher than those given in [8]. An orthogonal polarized patch antenna operating at 12.5 GHz and 14.25 GHz, i.e., with a frequency ratio of only 1.14 has been designed. The return loss, current distribution and radiation patterns of the element are discussed in detail. An 8 by 8 array has been further developed, of which gains more than 23.4 dBi have been obtained at dual frequencies. Measured results agree well with simulated ones, which demonstrate the desirable performances and efficiency of the proposed structure.

2. DESIGN OF A DUAL BAND PATCH ELEMENT

Orthogonal-mode dual-frequency patch antennas are usually obtained with a probe-fed configuration, which is displaced from the two principal axes of the patch [1]. The performance of this approach in terms of matching level and bandwidth is almost equal to that of the same patch fed separately on the two orthogonal principal axes. To obtain a uniplanar configuration, we can substitute the probe with a microstrip line. The microstrip line can be inserted into one edge and displaced from another dimension to achieve the simultaneous matching at the two frequencies with orthogonal modes. However,

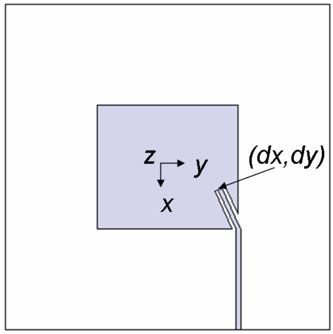
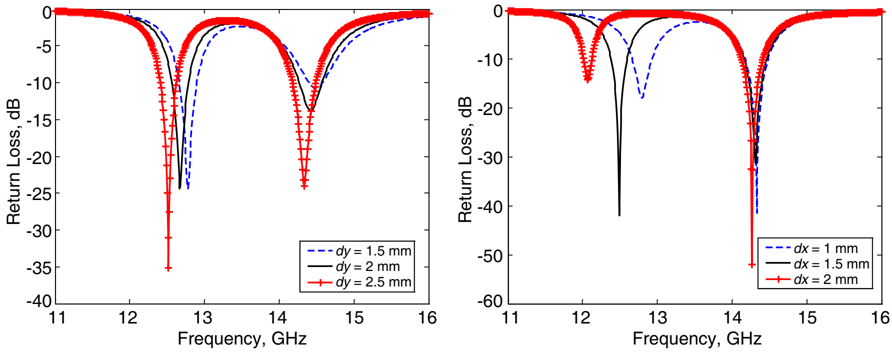


Figure 1. Layout of a dual band patch element.

the surface currents travel a longer distance along the recess, so that the corresponding resonant frequency decreases, which extremely limits the realizable minimum ratio of dual frequencies that is desired in some applications. To solve this problem, a corner-fed dual-band orthogonal polarization patch element shown in Figure 1 has been proposed. The microstrip line is inserted from the corner of the patch into the feeding point located at (dx, dy). It can be demonstrated that the surface currents mainly concentrate near the central part of the patch, so that deterioration of the low-band currents affect the lower resonant frequently slightly, and a very small ratio of dual frequencies can be realized.

In particular, we design a corner-fed dual-band orthogonal polarized patch operating at 12.5 GHz and 14.25 GHz to demonstrate the advantages of the proposed structure. 3D EM simulation software Ansoft HFSS has been employed as the parameter study tool. The substrate used is Arlon DiClad 880 ($\varepsilon_r = 2.2$) of thickness 0.508 mm. Firstly we determine approximate dimensions of the patch corresponding to operating frequencies. Next, parametric study is conducted to optimize the feeding point location. For dx and dy, we keep one of them being constant and vary the other. Then we obtain the corresponding simulated reflection coefficients shown in Figure 2. We can see that, for prescribed $dx = 1.52$ mm, the variation of dy affects the upper band more strongly than the lower band in terms of matching level. On the contrary, for given $dy = 2.6$ mm, the variation of dx influences the lower band much more than the upper band. Therefore, impedance matching for two bands can be adjusted much independently by varying dx and dy separately, which is similar to the probe-fed case. By properly adjusting the feeding point and tuning the path dimensions slightly, the simultaneous



(a) (b)

Figure 2. S parameters of the patch with various feeding locations. (a) $dx = 1.52$ mm, (b) $dy = 2.6$ mm.

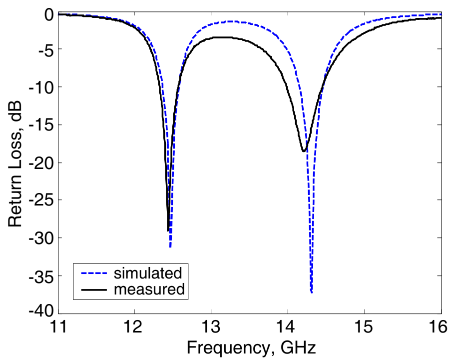


Figure 3. Measured and simulated return loss of the element.

matching level at the two frequencies with orthogonal modes has been achieved. Optimal parameters are obtained with the patch dimensions of 7.46 mm $\times$ 6.54 mm and feeding point location of $dx = 1.52$ mm and $dy = 2.6$ mm.

The patch antenna is fabricated. Simulated and measured results of return loss are shown in Figure 3. It is seen that bandwidth of 1.7% and 2.1% for simulated results and 2.0% and 3.3% for measured results are obtained at 12.5 GHz and 14.25 GHz, respectively. The current distributions at resonant frequencies are shown in Figure 4. It is seen that the currents mainly concentrate near the central part of the patch. The simulated and measured radiation patterns are shown in Figure 5. The simulated gains are 8.46 and 8.4 dBi and measured

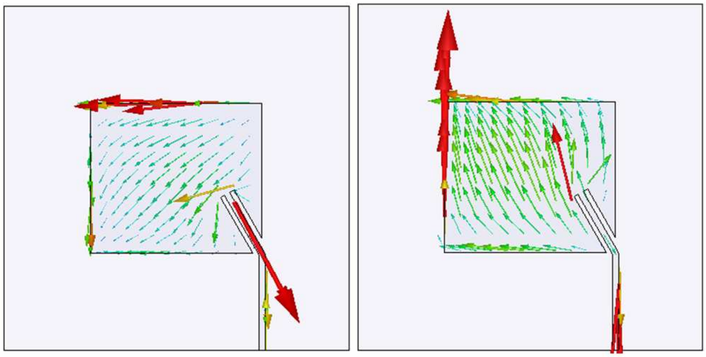


Figure 4. Surface current distributions of the element at (a) 12.5 GHz, (b) 14.25 GHz.

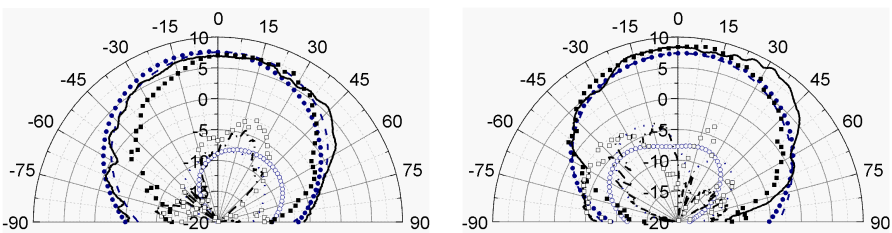


Figure 5. Simulated and measured radiation patterns of the element. (a) 12.5 GHz, (b) 14.25 GHz. - - - simulated E-plane copolar. — measured E-plane copolar. ... simulated E-plane crosspolar. –·– measured E-plane crosspolar. • simulated H-plane copolar. ■ measured H-plane copolar. ○ simulated H-plane crosspolar. □ measured H H-plane crosspolar.

ones are 7.31 dBi and 8.33 dBi at 12.5 GHz and 14.25 GHz, respectively. Cross polarization isolations are better than 10 dB. The radiation efficiency is calculated to be more than 95%, which is comparable to single-frequency patch. Measured results agree well with simulated ones, which demonstrate the desirable performances and efficiency of the proposed structure.

3. DESIGN OF AN 8 BY 8 ARRAY

The proposed uniplanar corner-fed patch element lends itself to form a dual band array as convenient as to form a single band array. An 8 by 8 corporate array shown in Figure 6 has been developed to demonstrate this advantage. For a particular application, the elements are declined to acquire ±45° linear polarizations. Element spacing $d = 18$ mm is chosen to acquire desirable efficiency, which is 0.75 and 0.855 free space wavelengths for 12.5 GHz and 14.25 GHz, respectively. The array is center-fed with a dual-frequency T-junction feed network. The small dual-frequency transformer with two sections [9] has been used to achieve dual band performance of the feed network. For simplicity, only the results for the total array are presented. Sixteen arrays have been tested. The widest bandwidths for two frequencies are 3.99% and 4.20%, as shown in Figure 7. The narrowest ones are 2.67%

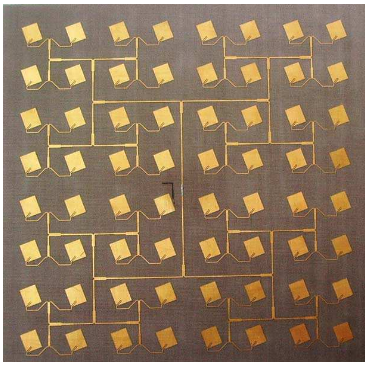


Figure 6. Photograph of an 8×8 array.

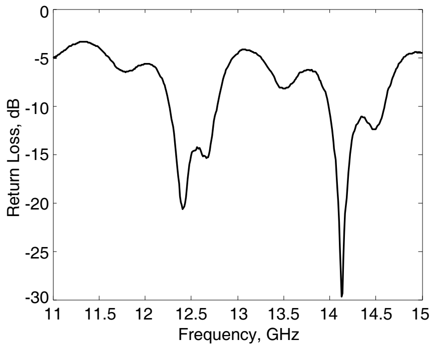


Figure 7. Measured return loss of the 8 × 8 array.

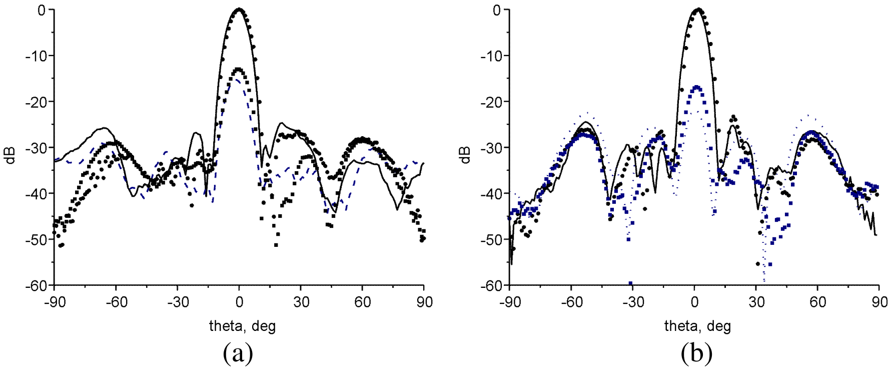


Figure 8. Measured radiation patterns of the 8×8 array. (a) 12.5 GHz, (b) 14.25 GHz. — *E*-plane co-polar. ● *H*-plane co-polar. - - - *E*-plane cross-polar. ■ *H*-plane cross-polar.

and 2%. The average values are 3.52% and 3.61%. The deviation is mainly due to the imperfect connection between SMA connector and the microstrip substrate. Measured radiation patterns of the array are shown in Figure 8. Measured results of gain are 23.8 dBi and 23.47 dBi at 12.5 GHz and 14.25 GHz, respectively. Cross polarization isolations are better that 13 dB. The total efficiencies are 53.9% and 38.3% for 12.25 GHz and 14.25 GHz, respectively.

4. CONCLUSION

In this paper, a coplanar corner-fed design on dual-band orthogonal polarized patch array element is presented. The corner-fed configuration provides desirable impedance matching for dual orthogonal polarized modes TM_{010} and TM_{001} at two different frequencies with a small frequency-ratio of 1.14. Good performances of impedance bandwidth and radiation pattern are achieved for the dominate modes. Although the cross-polarization performance is deteriorated by the limitation of patch dimensions and the insertion part of the corner feed, the proposed patch antenna element keeps very compact structure which lends itself to form an array. A dual-band 8-by-8 array with 23.8 dBi and 23.47 dBi gains has been developed, which demonstrates the desirable performances and efficiency of the proposed structure.

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