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BROADBAND AND HIGH-GAIN E-SHAPED MICROSTRIP ANTENNAS FOR HIGH-SPEED WIRELESS NETWORKS

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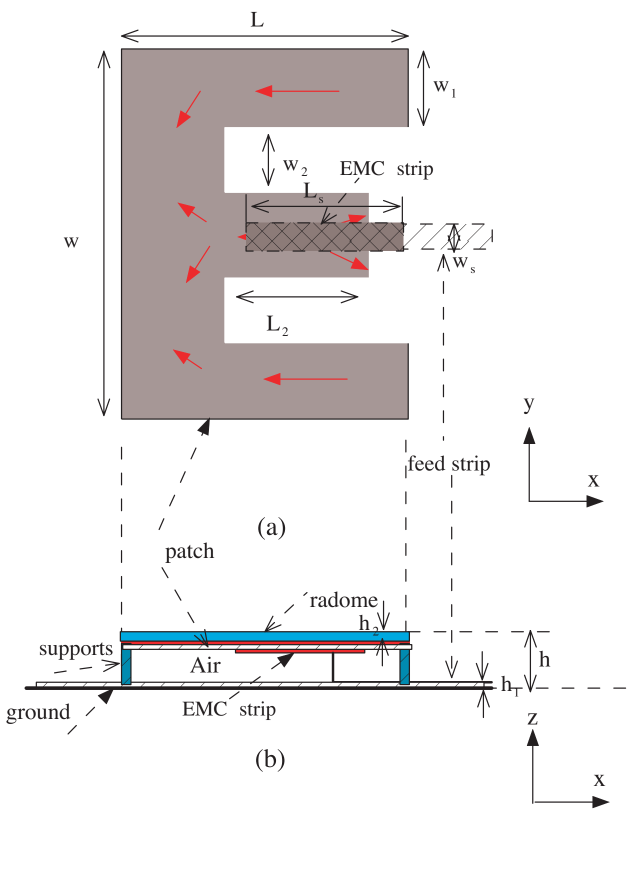
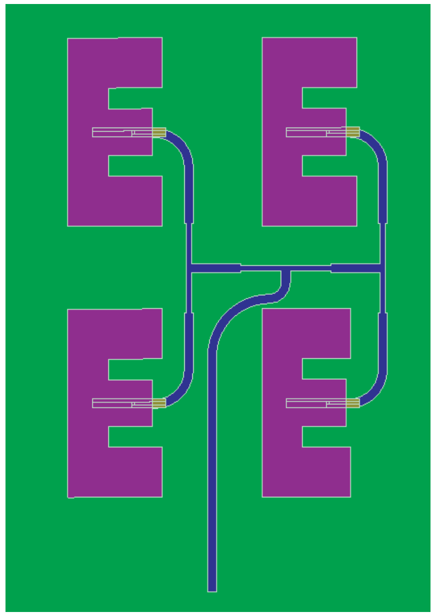
Abstract—New electromagnetically coupling fed low profile broadband high gain E-shaped microstrip antennas (MSA) were proposed for high speed wireless networks in IEEE 802.11 a and j standards. The proposed antenna uses an E-shaped microstrip patch covered by a radome and fed by an electromagnetically coupled strip. To validate this concept, a single antenna element and a sub-array were designed, built and measured. The measured results indicate that the element and the sub-array cover the band from 4.8 to 6.0 GHz (return loss < -10 dB) and produce a gain of 8 dBi and 11 dBi, respectively. The developed prototypes may find their applications in wireless communication networks as mobile or base antennas.

1. INTRODUCTION

Wireless local area network (WLAN) is rapidly growing its applications in wireless communications. Antennas for portable WLAN devices require broadband, low profile, high gain, and compact design. As a result, multiband antenna techniques have attracted extensive attentions. Recently many new technologies have been proposed for multi-band antenna designs [1–5]. For example, cutting slots on a metal patch to form an E-shaped is one of the current solutions [6–11].

As known well from available literature, almost all E-shaped MSAs are fed by a coaxial probe for a coaxial feed [4, 5], which can be easily built in a single radiation element. However, a coaxial probe is undesired in integrated implementation, and this approach is also not suitable for large antenna arrays due to mass vias or pins [12, 13]. In order to overcome the above problems, an electromagnetically coupled (EMC) technology is employed to develop a ultra-low profile compact E-shaped MSA and a related sub-array. Compared to other available E-shaped MSA designs, the proposed design avoids using vias or pins. Therefore, it greatly reduces cost and errors in fabrication, especially in a large array. In addition, a low cost radome is first considered to cover E-shaped MSA. This additional substrate layer not only increases the bandwidth and the gain of the antenna, but also provides necessary mechanism protection for the radiation element as well. With the above design considerations, a single radiation element achieved below features: 1) The bandwidth of a single element is up to 36% (from 4.8 to 6.7 GHz) while the antenna maintains a thin thickness of $0.1\lambda_0$ at the center frequency $f = 5.8$ GHz, 2) A smooth high gain of 8 dBi is obtained across the operating band. In order to achieve a higher gain,





(c)

Figure 1. The configuration of the proposed antenna. (a) Top view, (b) side view, and (c) 2 by 2 sub-array. $L = 15\,\text{mm}$, $W = 25\,\text{mm}$, $W_1 = 8\,\text{mm}$, $W_2 = 7\,\text{mm}$, $h_2 = 1.47\,\text{mm}$, $h_1 = 0.81\,\text{mm}$, $h = 5.78\,\text{mm}$, $\varepsilon_2 = 2.9$, $\varepsilon_1 = 4.4$, $\tan\delta_1 = 0.02$, $\tan\delta_2 = 0$, $w_s = 1.54\,\text{mm}$, $L_s = 10\,\text{mm}$.

a corresponding 2 by 2 sub-array was also developed. The sub-array maintains almost the same useful impedance width as a single element and has a significantly increased gain.

2. ANTENNA DESIGN

Figure 1 shows the proposed antenna structure. In the element design, an E-shaped patch is etched on the top side and a rectangular strip on the bottom side of FR4 substrate. As illustrated in Fig. 1, this feeding strip is connected to another vertical strip that goes through an air layer and then connects to a 50 Ohm microstrip feedline on a ground substrate. For this design, the size of the ground plane is 40 mm by 50 mm. In the sub-array design, four identical elements are employed to build a 2 by 2 sub-array as shown in Fig. 1(c), where the element spacing is $0.6\lambda_0$ in the x-axis and $0.75\lambda_0$ in the y-axis

(λ_0 is the wavelength at operating frequency). For good impedance matching, several quarter-wavelength transfers are used to connect the radiation elements and the parallel feed networks. The other structure parameters are shown in Fig. 1, and these parameters are chosen to fulfill the specified bandwidth requirements suitable for IEEE 802.11 a and j standards.

3. RESULTS

To validate the proposed design, a single element and a corresponding 2 by 2 sub-array were analyzed and simulated using IE3D software package [14] as a CAD tool. Based on these simulations, antenna prototypes were also fabricated and measured. The obtained results are presented below:

The return losses for a single element and a sub-array were first studied, and the obtained results are shown in Fig. 2. It can be observed that the single element and the sub-array achieve both almost the same impedance bandwidth up to 30%. This fact indicates that the designed feed networks achieve good impedance matching, which allows the sub-array achieves high radiation efficiency due to less feed network losses.

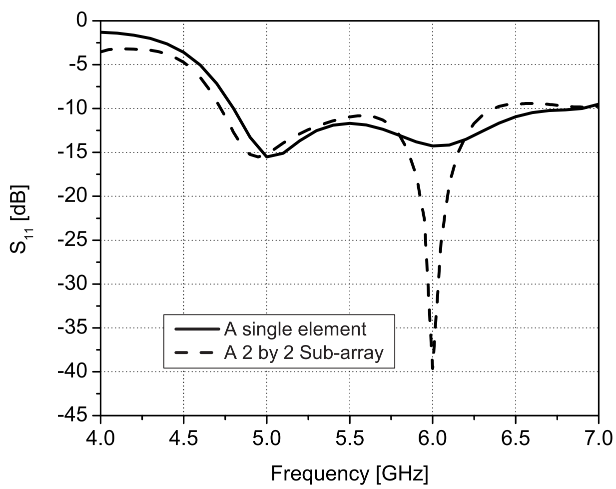
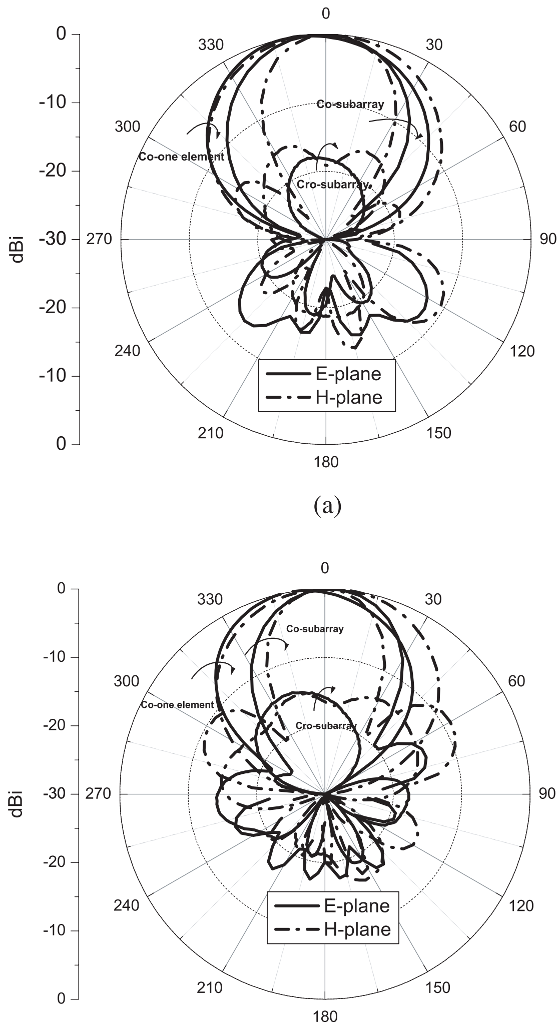


Figure 2. Measured return losses of the proposed antenna.

Next, the far-field gain patterns in the two principal E-and H-planes were measured at $f = 4.9$ and $5.8\,\text{GHz}$ for the single element and the sub-array. Fig. 3 shows the obtained patterns. Associated



(a)

(b)

Figure 3. Measured radiation patterns at 4.9 and 5.8 GHz.

with Fig. 1, for the E-plane pattern E_θ is in the $\phi = 0°$ plane whereas for the H-plane patterns E_θ is in the $\phi = 90°$ plane. As expected, the sub-array achieved higher gain than a single element.

Finally, the gain versus frequency was measured for both single element and related sub-array. The results are presented in Fig. 4. These results indicate that the single element and the sub-array achieve

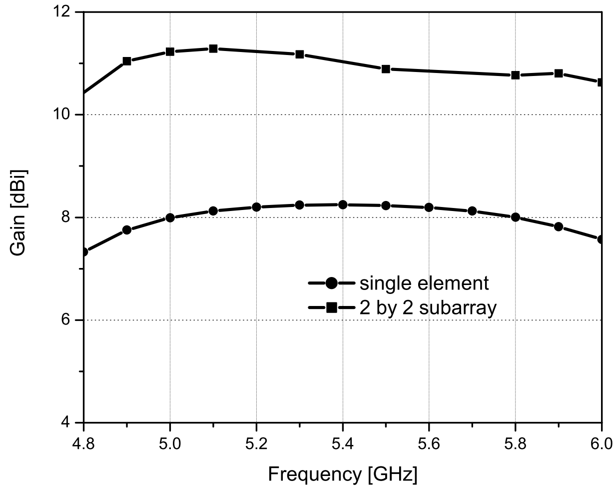


Figure 4. Measured gain vs operation frequency.

a smooth gain across the operating band, and their average gains are around 8 and 11 dBi, respectively.

4. CONCLUSION

In this paper, new electromagnetically coupled (EMC) strip fed low profile broadband high gain microstrip antennas have been developed. The designed single element antenna and the 2 by 2 sub-array both achieve the impedance bandwidth of more than 30% and the average high gain of about 8 dBi and 12 dBi, respectively. Since a rectangular microstrip line couples electromagnetically energy to the MSA, the feeding avoids vias or pins to connect the MSA and the feedlines. This advantage over a coaxial probe is specially suitable for a large array antenna design. Although the antennas take multi-layered structures, they still maintain ultra-low compact profile. With these features, the proposed antennas can be used in high speed wireless networks, especially for IEEE 802.11 a and j standards, as mobile or base station antennas.

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