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ULTRA WIDEBAND ROSE LEAF MICROSTRIP PATCH ANTENNA

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Abstract—In this paper a novel rose leaf shape microstrip antenna with capacitively coupled rectangular fed is presented. Various shapes of capacitive coupled fed are compared and optimized by successive iterations of a computer-aided analysis. The Ansoft HFSS is employed for analysis at the frequency band of 4.3 GHz–8.3 GHz. The antenna is fabricated and measurement results show a very good agreement with the simulation results. The proposed antenna is able to achieve an impedance bandwidth about 69%. Effects of varying the parameters on the performance of the antenna have also been studied. The proposed antenna can be used in wireless ultra-wideband (UWB) communication.

1. INTRODUCTION

Microstrip antennas are used in a broad range of applications from radars, telemetry, navigation, biomedical systems, mobile satellite communications, the direct broadcast system (DBS), global positioning system (GPS) for remote sensing.

Conventional microstrip antennas, in general, have a conducting patch printed on a grounded microwave substrate. Also, they have attractive features of low profile, light weight, easy fabrication, and conformability to mounting hosts. However, microstrip antennas inherently have a narrow bandwidth. So, bandwidth enhancement is usually demanded for practical applications. Nowadays, to meet miniaturization requirements of mobile units, smaller size of antenna is usually required for applications in mobile communication systems. Thus, size reduction and bandwidth enhancement are major design considerations for practical applications of microstrip antennas [1].

As a result, studies for achievement of compact and broadband operations of microstrip antennas have really increased and various designs have been proposed and implemented to enhance this effect.

A numerical analysis and design of a printed tap monopole antenna with a small size for UWB wireless communications applications was presented in [2]. A slit, tapered transition and two-step staircase notch are implemented to obtain the ultra wide bandwidth of the antenna. Many techniques like as meandered ground plane [3], slot-loading techniques [4], stack shorted patch [5, 6] and chip loading [7, 8] techniques have been reported to achieve wideband and small size of microstrip antennas.

On the other hand, a wideband dual-polarized dual band antenna is designed and presented for current personal wireless communication applications at 0.9, 1.8, 1.9, and 2.4, 5.2 and 5.8 GHz [9, 10] and also, the square-ring slot antenna is designed, fabricated, optimized and measured for Ultra Wideband applications [11]. The major problem associated with impedance matching is the large probe reactance owing to the required long probe pin in the thick substrate layer. To solve this problem, a variety of designs with modified probe feeds have been reported. One suitable design method is to choose capacitively coupled feed in which the probe reactance compensation can be obtained [12–14] and a typical broadband microstrip antenna is presented [15]. Two different radiating elements are connected to each other through a matched section and are embedded on a single layer structure. The structure offers a dual-band microstrip antenna.

In [16], two new line-fed loaded planar antennas are proposed for ultra-wideband applications. The first antenna is a circular patch with a circular ring as a Defected Ground Structure (DGS). The second configuration is a rhomboidal patch which a $50\,\Omega$ microstrip line passes through it.

The bow-tie slot antenna is a broadband design conventionally used in many communication applications. An ultra-wideband bow-tie slot antenna fed by CPW is proposed in [17]. This antenna has been demonstrated to provide an UWB with return loss less than -10 dB from 9.5 GHz to 22.4 GHz. The bandwidth is up to 80%, which is quite better than the traditional bow-tie slot antenna [17].

The low bandwidth of an inductively coupled straight dipole slot can be overcome by utilizing a bow-tie slot as proposed in [18].

In [19], a piece of glass, much thicker than formal substrate thickness, has been used as substrate of an UWB antenna. Using a piece of thick glass as substrate of the antenna causes a very simple configuration, very low cost and a high impedance bandwidth which covers the whole FCC band.

Recently, a set of compact planar slot antennas for ultra wide band applications for microwave imaging and wireless communication applications are presented. These antennas provide bandwidth of more than 7 GHz and are designed for frequency range of 3–10 GHz [20].

In [21] a single-layer coplanar waveguide (CPW)-fed planar monopole antenna consisting of a rectangular microstrip patch with double-cornered notches to obtain dual wideband operations covering UMTS/IMT-2000 and 5.2/5.8 GHz WLAN bands is presented.

To achieve desirable wide impedance bandwidth, structural parameters of fractal bowtie antennas are optimized in an automated design, making use of the Genetic Algorithm (GA) in conjunction with NEC (Numerical Electromagnetic Codes) and cluster parallel computation [22].

The dual-F-shaped radiating element and a 50 Ω microstrip line are investigated in [23]. The proposed antenna is light in weight, low in cost and easily to construct. The effort has been done on the impedance bandwidth through changing different parameters of the antenna configuration to obtain the ultra wideband characteristic [23].

It is for decades that monopole antenna which can be designed in various shapes serves as one of the best antenna types for UWB applications. The planar monopole for instance, can come in circular, printed square, rectangular, swallow-tailed planar, hexagonal and pentagonal shapes [24, 25].

In this paper a novel UWB rose leaf shape microstrip antenna with capacitively coupled rectangular fed is presented. Main idea of the proposed design is based on the usage of rectangular capacitively coupled feed, suitable slot loading on the radiating surface. Moreover, an air/foam substrate is employed to obtain the maximum antenna bandwidth. This method can be successfully used to achieve an efficient and wideband antenna for high-speed (802.11a 54 Mb/s) wireless computer networks and other similar communication systems.

2. ANTENNA STRUCTURE

To obtain the proposed antenna, a simple method is to subtract the small and suitable tapered slots from a simple circular patch antenna. The resulting antenna is illustrated as the black area in Fig. 1.

The radiating patch of the proposed antenna is separated from the ground plane by an air/foam filled substrate in the upper layer. The antenna is capacitively fed via a probe fed small rectangular patch in which the vertical probe is made from a 50 Ω coaxial connector with an inner diameter of 1.25 mm. Different shapes of feed such as triangular fed, semicircle fed and rectangular fed are used and the dimensions of each feed are optimized to achieve the best result for the antenna bandwidth. As an example, effect of the different value of semicircle radii on the antenna bandwidth is investigated in Fig. 2.

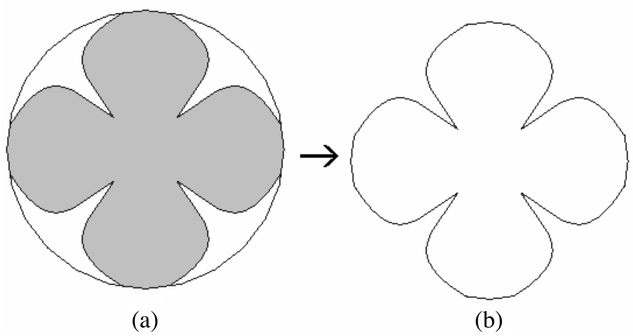

Figure 1. Geometry of proposed microstrip patch antenna. (a) Conventional circular patch. (b) Final designed patch.

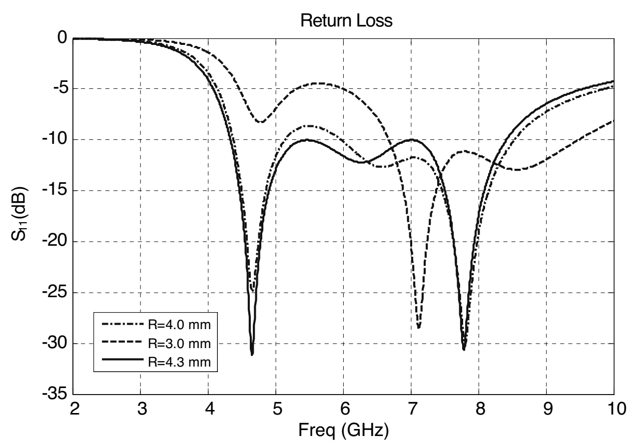

Figure 2. Simulated results of the antenna return loss for different value of semicircle radii.

The optimization procedure was done for all feeds and Fig. 3 shows the best result of the antenna return losses in the end of the procedure.

Using the simulation results, the optimum values of feed's dimensions are:

- Radius of semicircle feed = 4.3 mm.
- Each sides of equilateral triangle feed = 3.3 mm.
- Dimensions of rectangular feed = 4.5 mm × 8 mm.

Furthermore, input impedance behaviors of three mentioned types of feed in different frequencies of the antenna bandwidth are illustrated over the Smith diagram in Fig. 4. Good impedance matching for all shapes of feed over the antenna bandwidth is achievable.

Based on the above results, the rectangular feed is used as a best

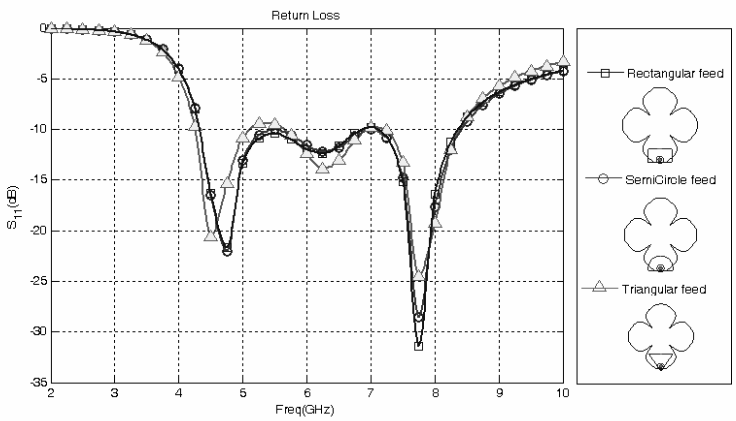

Figure 3. Simulated results of the antenna return loss for different shapes of optimum capacitive coupled feds.

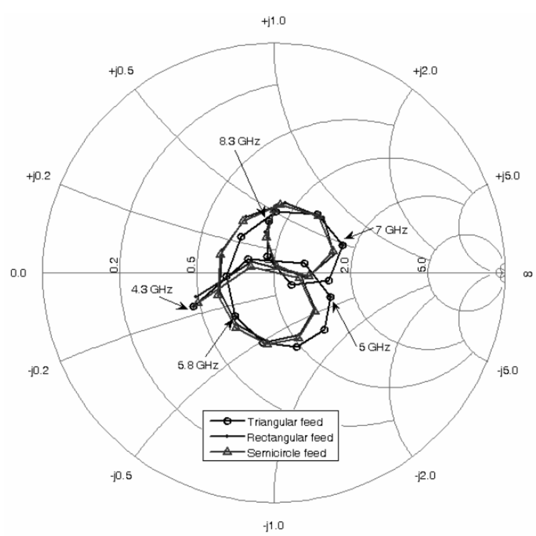

Figure 4. Simulated results of the input impedance of antenna for different shapes of capacitively coupled feed.

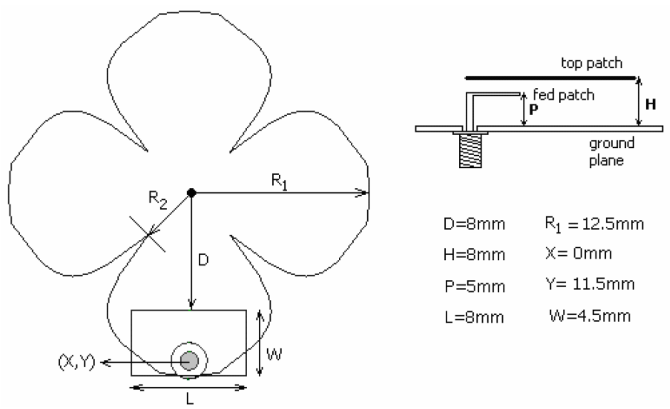

Figure 5. Geometry of proposed wideband microstrip patch antenna with capacitively coupled rectangular feed (Ground size: 10 cm * 10 cm).

candidate. The related dimensions of presented antenna are also given in Fig. 5.

In this case, the probe position of coax fed is optimized and then is placed from the rectangular side by a distance of 1 mm. At this condition, the energy is coupled by groups of adjacent resonant modes from the rectangular fed to the radiating surface patch. In order to obtain the most widely impedance bandwidth the adjacent resonant modes must be excited with good impedance matching. Fig. 6 shows the simulated return loss of the new antenna design considering R_2 as a parameter.

The depth of loaded slot (R_2) on the antenna radiation patch is varied from R_1 (complete circle) to a non zero value. The return loss of proportional antenna in Fig. 5 is simulated and compared to obtain the optimum value of R_2. It can be seen from Fig. 6 that the antenna bandwidth varies with R_2 and finally, the value of $R_2 = 4.6$ mm is obtained for the best response. Within the optimum design, a group of three adjacent resonant modes for the proposed antenna can be excited with suitable impedance matching, and a wide impedance bandwidth is formed. The center frequency of our proposed antenna is designed at around 6 GHz. The definition of fractional bandwidth used in this paper is:

$$BW\% = \frac{f_2 - f_1}{\sqrt{f_1 f_2}} \times 100 \tag{1}$$

where f_1 and f_2 are the lowest and highest frequencies at which the S_{11} is under 10 dB level. To reach a better performance and excellent

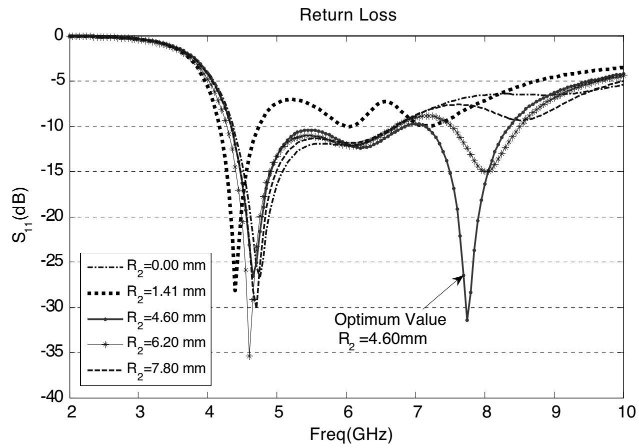

Figure 6. Simulated results of the return loss of proposed antenna in Fig. 2 for different values of R_2.

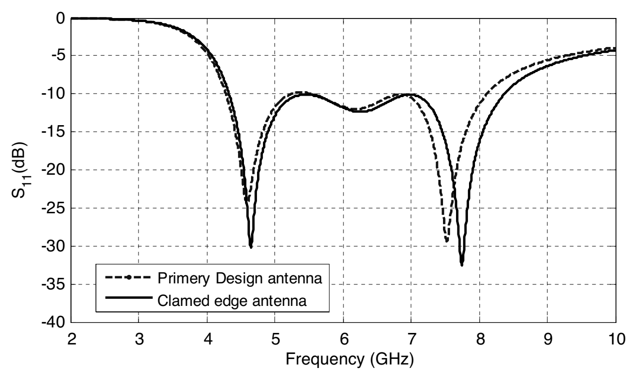

Figure 7. Simulated return loss of primary design and clammed patch antenna.

design, the sharp edges of patch were calmed and sharp edges have been smoothed out.

Simulated return loss of primary design and clammed patch antenna are shown in Fig. 7.

It is clear from Fig. 8 that the clammed antenna has a wider impedance bandwidth and the antenna bandwidth increases about 6%.

This is because of the accumulation of time varying electric charges in the sharp corners of slots in the primary antenna. On the other hand, the accumulated charges in the corners can be treated as strong

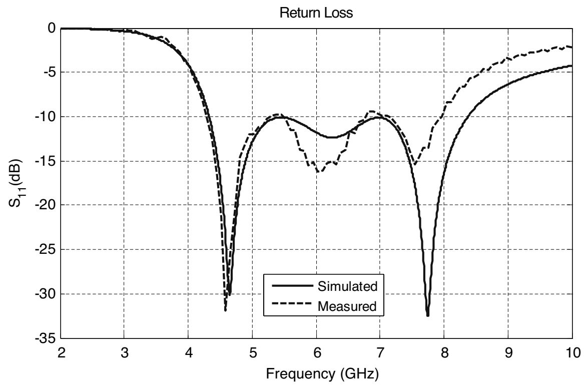

Figure 8. Measured and simulated Return loss of proposed antenna vs. frequency.

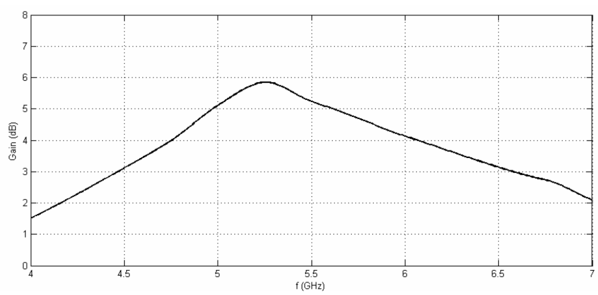

Figure 9. Antenna gain measurement.

sources able to make some distortions in the antenna radiation pattern and other antenna parameters.

In fact, the wavelength of source power in low frequencies is great compared to the dimensions of sharp corner of the tapered slots. So, the effect of sharp corner clamming on return loss is not noticeable as it can be seen in Fig. 7. However, when the wavelength becomes small at high frequencies compared to the dimensions of slot corners, the effect of clamming becomes most sensitive. Therefore, the antenna bandwidth increases from 3.82 GHz (4.3–8.12 GHz) to 4.06 (4.3–8.36 GHz) in this case.

In the next stage, the measured and simulated results of the return loss of final design of proposed antenna using the finite element method are presented. The measured radiation patterns and measured gain are presented over the suitable figures and tables at the different frequencies in the bandwidth of antenna.

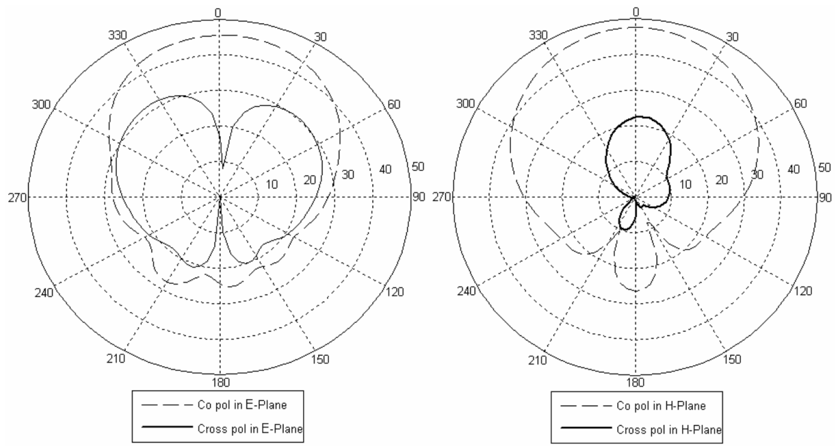

Figure 10. Measured co-pol and cross-pol radiation patterns at three frequencies of 4.6 GHz.

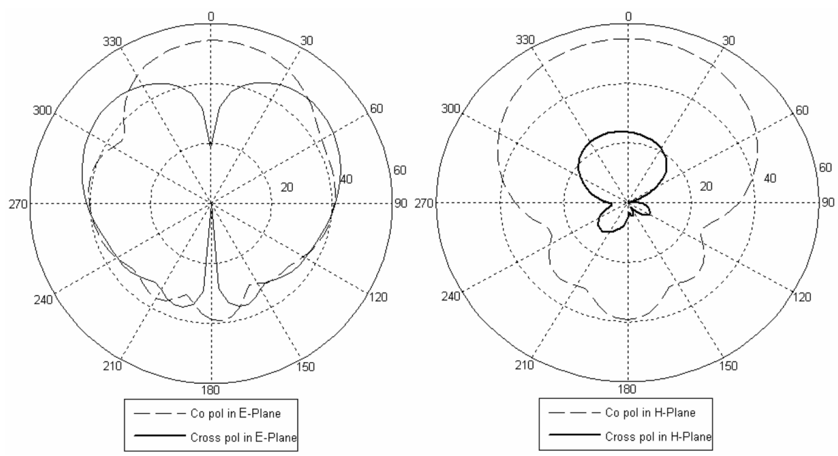

Figure 11. Measured co-pol and cross-pol radiation patterns at three frequencies of 5.45 GHz.

3. MEASUREMENT AND SIMULATION

According to design conditions, the simulation and measurement results of the return loss for the proposed antenna are shown in Fig. 8. It shows that for -10 dB return loss, the bandwidth is approximately 69% (in simulation) and 66% (in measurement) which is the large achievable bandwidth obtained so far.

Table 1. Specification of proposed antenna (BW = 69%).

	Simulation	**Measurement**
Resonant Frequencies (GHz)	4.65 6.28 7.76	4.8 6.31 7.78
S_{11}(dB)	−30.16 −12.38 −32.49	−26.02 −17.21 −20.51

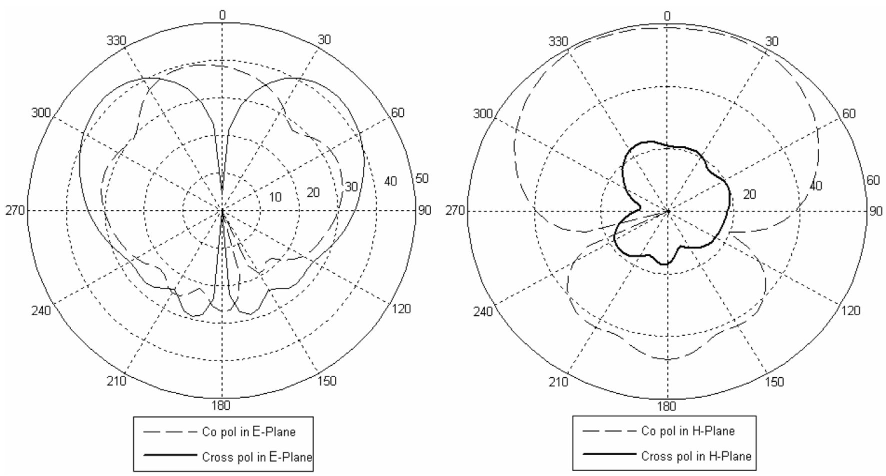

Figure 12. Measured co-pol and cross-pol radiation patterns at three frequencies of 6.3 GHz.

The specifications of three resonant frequency of fabricated antenna are presented in Table 1.

The antenna gain was measured in antenna lab and the result was presented in Fig. 9. As can be seen, the antenna gain within the C-band is found to range from approximately 1.5 dB to 5.9 dB and 3 dB gain bandwidth is about 4.4–6.6 GHz (about 41%). The efficiency is about 74% and it is noticeably high, since there are no high dielectric losses and no surface wave losses.

Figures 10–14 show the co-polar and cross-polar measurement of the E-plane and H-plane radiation pattern at different frequencies at antenna radiation band (All scales are in dB). The high cross-polarization in some frequencies is a result of the leaky radiation of

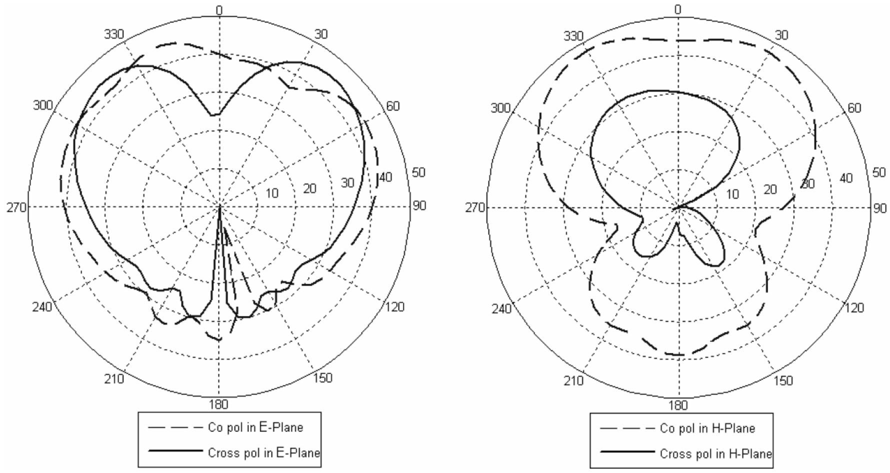

Figure 13. Measured co-pol and cross-pol radiation patterns at three frequencies of 7 GHz.

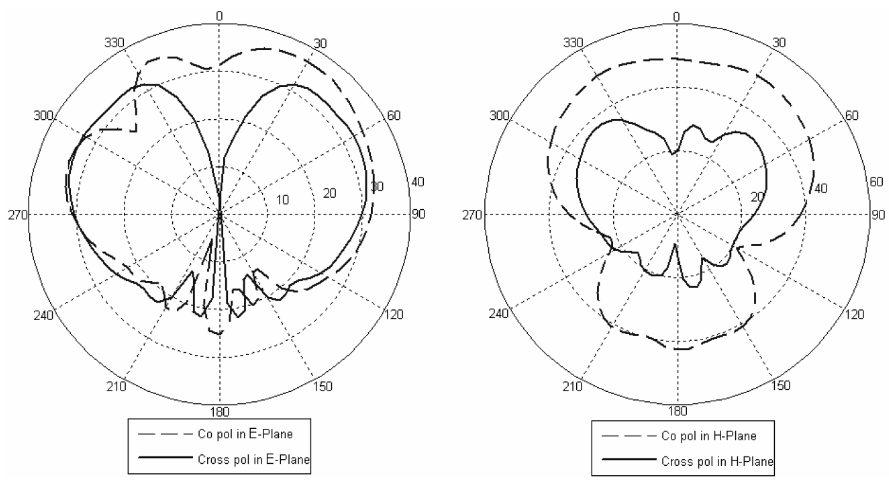

Figure 14. Measured co-pol and cross-pol radiation patterns at three frequencies of 7.5 GHz.

rose leafs.

It can be seen that the good broadside radiation patterns are observed, and the cross polarization radiation in the H-plane is seen to be less than -20 dB, however the cross polarization in the E-plane is greater.

4. CONCLUSION

The low-profile rose leaf shaped patch antenna with wide bandwidth is presented in this paper. Measured results on fabricated antenna were used to confirm the simulation results. It is also helpful to understand the interaction and performance of the antenna and the communications system in wireless packages. The results and design details on the antenna presented here can be chosen as the beginning design for professionals interested in utilizing low-profile integrated antennas. At the end, a 69% bandwidth rose leaf shape patch antenna is designed, measured, and characterized in details; It can be applied to modern wireless communication frequencies of 4.175–8.5 GHz.

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