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Design of a Circular Slotted Antenna for Wireless Agriculture Applications

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Abstract: In this paper, a circular-slot dual band antenna fed by a coplanar waveguide (CPW) for smart agriculture applications is presented. This paper presents design for sensing of soil moisture and transmitting to an external receiver. The antenna mainly encompasses a ground with a wide circular slot in the Centre, a rectangular feeding strip and two pairs of asymmetric planar inverted L (APIL) strips connecting with the slotted ground. The tuning effects of the rectangular patch, ground size, and APIL strips to the resonance and matching condition are examined by HFSS and the prototype is fabricated and measured. The simulated results show that the proposed antenna has two good impedance bandwidths (VSWR less than 2) and gain of 4.78dB and which can cover the Wi-Fi 5.2/5.5/5.8 GHz . Moreover, the obtained radiation patterns demonstrate that the proposed antenna has significantly directional and Omni directional patterns in both E-plane and H-plane.

Keywords : *CPW, APIL,HFSS.*

1. INTRODUCTION

As India is majorly dependent on agriculture and many hazardous effects on the crops can be seen so loss of the crops are loss to our nation. The economic contribution of agriculture to India's GDP is steadily declining because of the hazardous effects, still, agriculture is demographically the broadest economic sector and plays a significant role in the overall socio-economic fabric of India. Indian Agriculture is one of the most significant contributors to the Indian economy. Agriculture is the only means of living for almost 60% of the employed class in India. The agriculture sector of India has occupied almost 43% of India's geographical area. Agriculture is still the only largest contributor to India's GDP (16%) even after a decline in the same in the agriculture share of India. Agriculture also plays a significant role in the growth of socioeconomic sector in India.

In this paper, a resonant frequency antenna for Wi-Fi band applications is proposed, which is fed by a Coplanar waveguide (CPW). The antenna mainly comprises of a ground with a big circular slot in the Centre, rectangular feeding strip as radiating patch, and introducing two pair of asymmetrical planer inverted L Shaped slits connecting the ground. Compared to those designs shown in the literature, the antenna not only has better performance of interference suppression but also has compact size, large bandwidth and high gain. The simulated results about impedance bandwidth, radiation pattern and gain are discussed in detail in the next section.

2. ANTENNA DESIGN

The microstrip patch antenna analysis is represented by some models such as the transmission line model, cavity model, full wave model and characteristic model. The cavity model is more accurate and gives a good physical insight thus very complex compared to the transmission line model that is the simplest of all models and less accurate. The characteristic mode is typically performed on electrically small to intermediate size antennas for simplicity[3]. However, the full wave model is the most accurate and complex of the models and can analyze single elements, arbitrary shaped elements and infinite antenna arrays. The transmission line model is used in this work because of its simplicity to implement and its output good performance in antenna designs in terms of efficiency and return loss and also it is well suited for microstrip patch antenna design. By choosing operating frequency and a substrate with the required permittivity, and also defining the substrate thickness h, the design starts. Based on the transmission line model, the length L and width W of the patch are calculated as [5]

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

$$L = \frac{c}{f\sqrt{\varepsilon_{ref\ fUofo}}} - 2\Delta L$$

Where L is the length of the patch, W is the width of the patch, Fo is target resonance frequency, *c* is the speed of light in vacuum and the effective dielectric constant can be calculated by the equation[1]

$$\varepsilon_{\mathrm{reff}} = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Where *h* is the thickness of the substrate and ε_r is the dielectric constant of the substrate. Because of the fringing field around the periphery of the patch, electrically the antenna looks larger than its physical dimensions. ΔL takes this effect in account and can be expressed as:[1]

$$\Delta L = 0.412h\left[\frac{(\varepsilon reff + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon reff - 0.3)\left(\frac{W}{h} + 0.8\right)}\right]$$

Geometrical layout of the proposed antenna is shown. In this design the antenna structure is based on a wide-circular-slotted ground, two pairs of APIL's in the circular slot with the shorter end connecting with the ground, and the CPW feeding strip, as can be observed in Figure-1. The APIL's are applied to achieve the two band performances with sufficient VSWR less than 2. A rectangular shape is taken as overall design, and then cutting a circular slot in the middle of the rectangle. The antenna is imprinted on a 17 mm x 12 mm fiber glass resin FR4 substrate with dielectric constant of 4.6, thickness of 1.6 mm and a loss tangent of .02, fed by a 50Ω CPW transmission line two pairs of asymmetrical slots are inserted into the slotted area. Another rectangular slits are inserted in to the circular slots as CPW feed[4]. The optimal geometrical parameters of the proposed antenna are obtained by using Finite Element Method based simulation software simulator HFSS. The optimal dimensions are determined as follows (unit's mm):

L = 17,

W = 12,

L1 = 7,

W1 = 4,

L2 = 3.12,
L3 = 4,
L4 = 5,
L5 = 4.67,
g = 0.5,
W2 = 1.

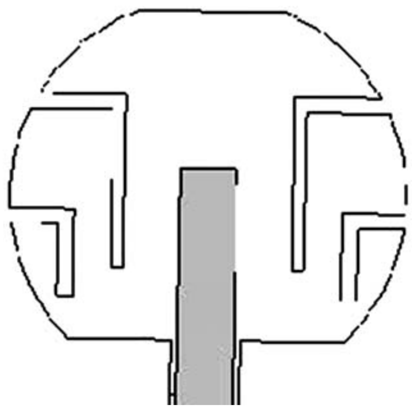

Figure 1: Design of antenna

3. RESULTS AND DISCUSSIONS

The design of the proposed antenna is shown in Figure-1. The S11 Parameter the antenna is shown in figure- 2.

The Gain of the proposed slotted circular antenna is shown in Figure-3.The obtained gains are 4.78dBi. Cross-polarization level is higher at H plane at the lower band. The radiation efficiency is 89.45% in the lower band and 97.97% at the higher band in the proposed antenna. This efficiency is broadly appropriate for Wi-Fi band applications. The co-polarization level in the E and H plane at both the band is relatively low, which is expected to be due to the diffractions from the edges of the small ground plane as shown in figure 4,5 6 and 7. This cross polarization level may be decreased by enlarging the ground plane size. It is shown from the results that significant directional and omni directional radiation patterns are obtained along the E-plane and H-plane respectively. This characteristic is convenient because the propagation environment of wireless communications devices is usually very complicated in practice.

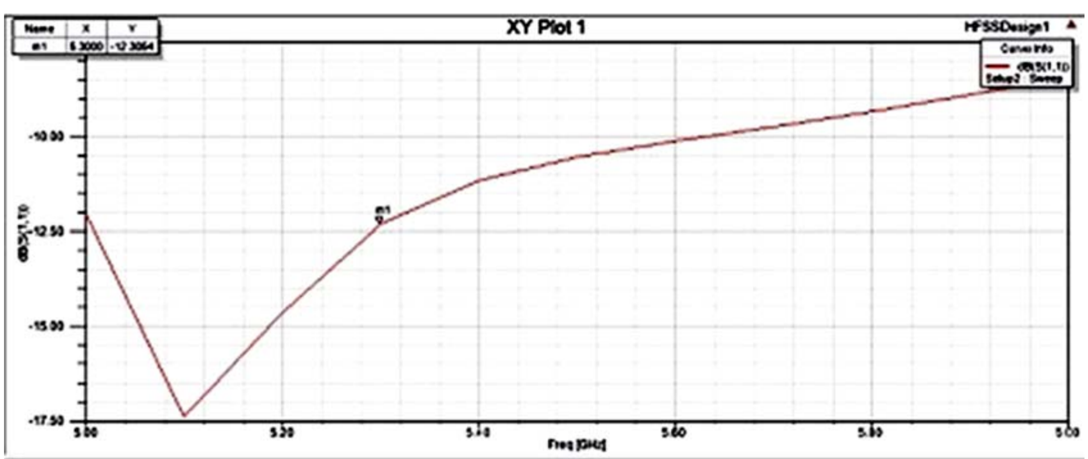

Figure 2: Plot of S11 parameter

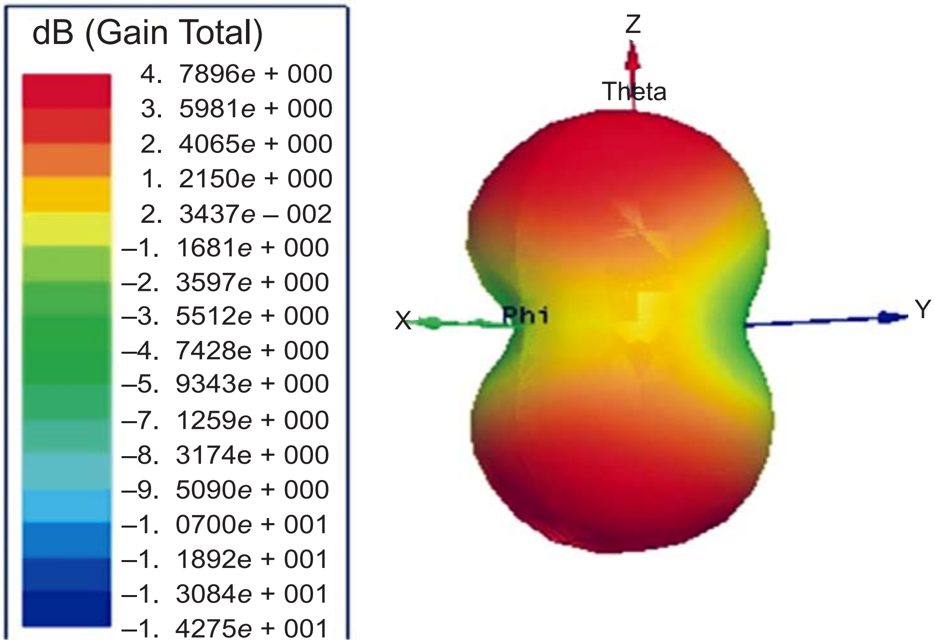

Figure 3: 3D Polar graph for gain

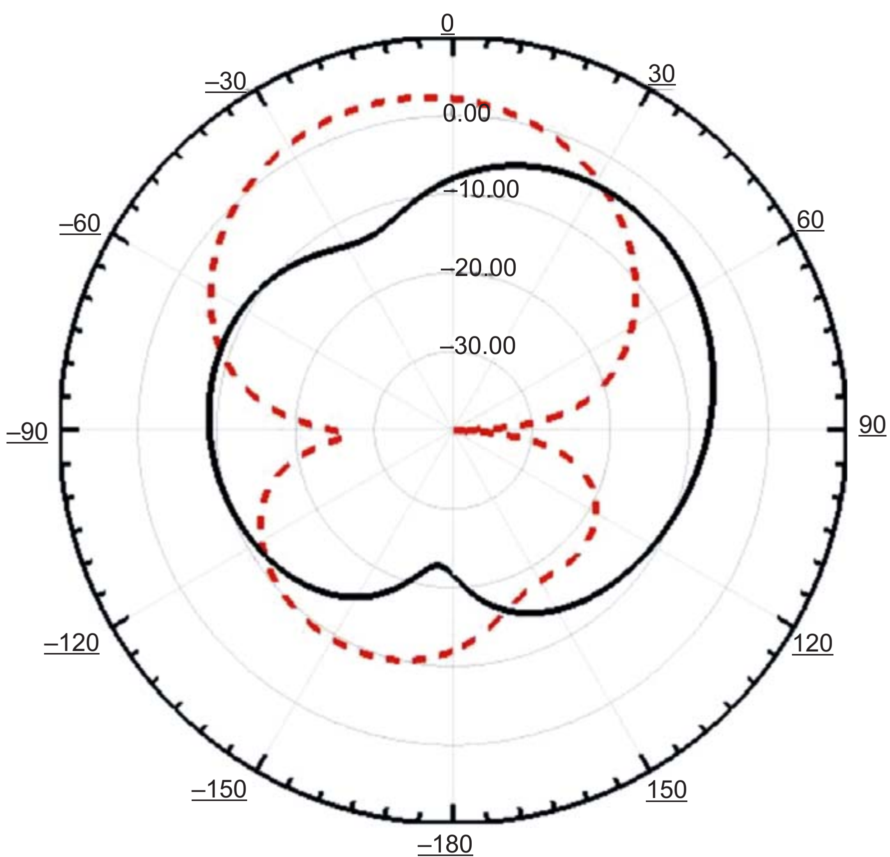

Figure 4

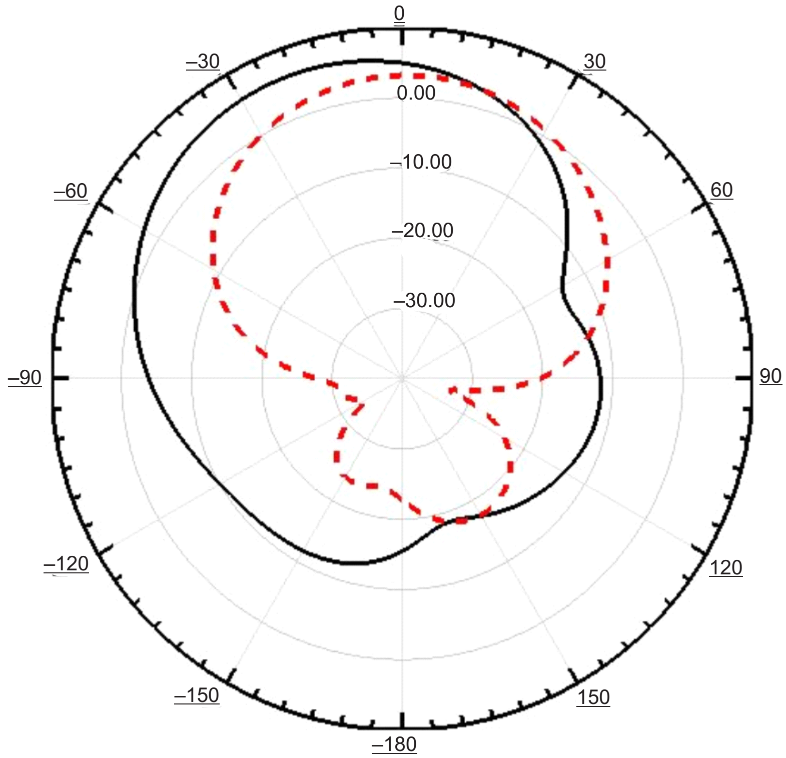

Figure 5

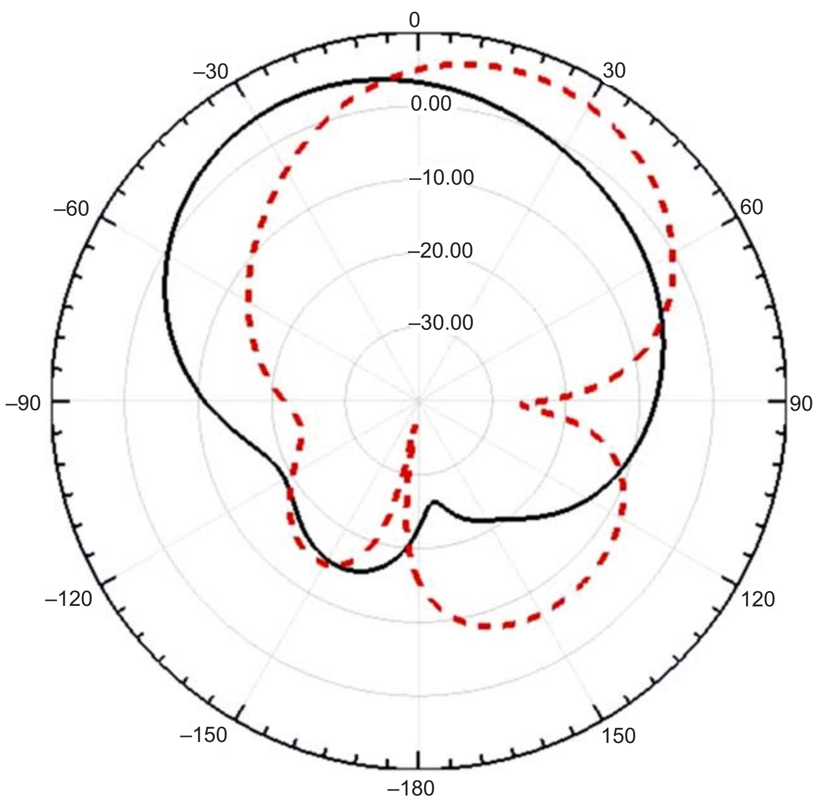

Figure 6

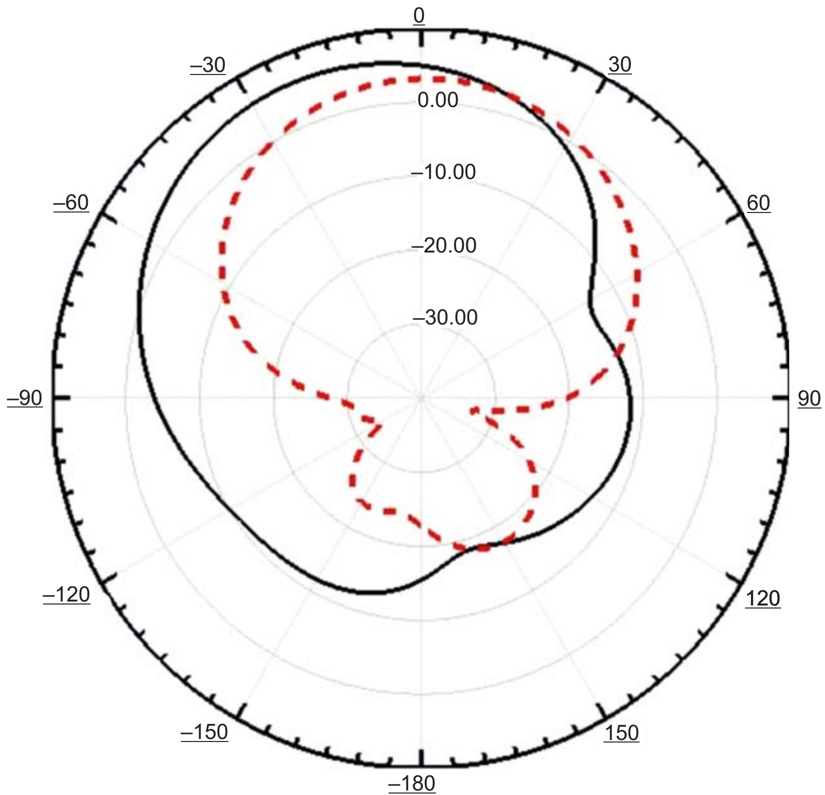

Figure 7

4. CONCLUSION

A CPW-fed circular-slot antenna with two asymmetric pairs of planar inverted L strips has been proposed and studied. The obtained frequency band of the proposed antenna is 5.3GHz which is wide enough to cover the required bandwidth of the Wi-Fi band applications. The proposed antenna has a gain 4.78dBi, and achieve less cross polarization in both the principal planes. This antenna is sensitive to soil moisture . This antenna can measure the moisture of the soil and can communicate this information to an outside controller for automatic sprinkler control or weather monitoring. Finally, the proposed antenna has good performance of interference suppression, excellent resonance character, good radiation pattern, and compact in size. This designate that the proposed antenna is well suited for smart agriculture applications.

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