International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 21 (2017) pp. 11345-11349

Design of Microstrip Patch Antenna with Polarization Diversity for Wireless Applications

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Abstract

In this article, microstrip patch antenna with polarization diversity is presented for wireless applications. The proposed antenna consists of two feeding modes; first one is broadside mode (TM_{11}) and second is conical mode (TM_{01}). These two modes are used to realize the polarization diversity. Triangular slot is made on patch which helps for achieving dual-band operation. The simulated and measured antenna design results are having good agreement among them. The proposed antenna has high isolation of -22 dB and good radiation characteristics in the desired frequency bands.

Keywords: Triangular slot, polarization diversity, broadside radiation, conical radiation**.**

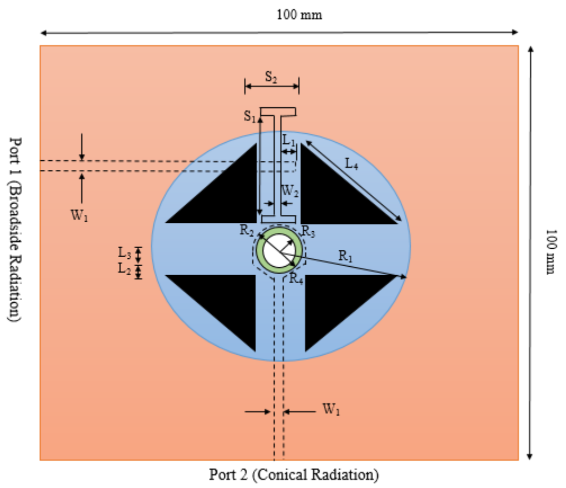
INTRODUCTION

The flexible structure, compact size and low fabrication cost, is making patch antenna popular. Various diversity schemes in antenna system enhance utility efficiency of spatial resources and finite spectra. To various diversity scheme patch antenna cannot be applied directly because of the disadvantage of restricted types of polarization, pattern and narrow bandwidth [1]. The demand of frequency reuse or polarization diversity in wireless communication systems is making dual-polarization performance a salient concept in designing of microstrip patch antenna. To achieve good cross-polarization levels as well as great isolation between different polarizations, several designs patch antenna giving dual polarized radiation at as single frequency is reported in [2-4]. The reflecting plate which is conducting is attached below ground plane gives a waveguide with existence of some propagation mode [5]. The use of probe-fed in patch antennas produces narrow bandwidth whereas the patch antenna with proximity coupling feed was found to be a good candidate for bandwidth enhancement [6]. The capacitive component is provided by the triangular slot by tuning the dimensions of slot, frequency of resonant mode due to slot can be controlled in reference to the resonant frequency of patch [7]. The circular patch operates in TM_{11} mode electric null exists to the center of patch by soldering of driven copper rod which helps to provide high isolation between two feeding ports [8, 9]. Port 1 is for TM_{11} mode which gives the broadside and TM_{01} mode gives conical side radiation by a proximity-coupled fed. [10, 11].

In this paper, the broadside and conical side modes are used to realise the diversity polarization. The use of proximity coupling technique helps to achieve good isolation. The triangular slot etched in the circular patch to realize dual band operations.

ANTENNA DESIGN

The proposed antenna structure with a combination of ground, substrate and patch is shown in Figure 1. The circular radiating patch has a radius of R1. The ground plane with an area covering 100 x 100 mm2 is implemented. This proposed antenna is composed of two FR4 substrate layers. An air-gap layer with a thickness of h is between the two split up substrates each having a thickness of 1.6 mm, dielectric permittivity, εr = 4.4 with tangent loss, tan δ = 0.02. The microstrip feed line impedance matching is fixed at 50 Ω



(a) Top-view

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 21 (2017) pp. 11345-11349
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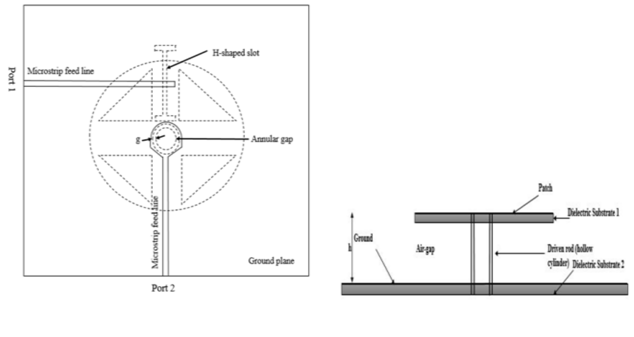
The H-shaped slot is etched in ground plane of the proposed antenna design with a dimensions of S_1 x W_2 and S_2 x W_2 for middle arm and two side arm respectively as shown in Figure 1(b). It is used to enhance the impedance matching performance of the antenna design.



(b) Bottom-view **(c) Side-view of an antenna**

Figure 1: Geometry of a proposed antenna structure

Figure 1(c) displays side-view of the proposed antenna and also position of different layers. The driven copper rod is soldered to the middle of patch and also on bottom surface of the substrate 2. The ground layer is placed over dielectric substrate 2. Ground layer is also having a cleavage circle working as an annular gap of radius 7.6 mm along with H-shaped slot.

Table 1: Parameters and dimensions of the proposed antenna

Parameters	R_1	W_1	W_2	L_1	L_2	R_3
Dimensions (mm)	25.9	3	2	4.5	4.5	6
Parameters	S_1	S_2	R_2	h	G	R_4
Dimensions (mm)	21.5	7.5	7.8	9.6	1	7

To keep current distribution of TM_{01} mode separated by the slot, the H-shaped slot will be placed parallel to the radial line of the circular patch. Through a 50 Ω microstrip line excitation of port 1 is done which is placed on substrate 1. This has adjustable stub with a length of L1. The simulations are done in and measured results can be found out by Vector Network Analyzer.

RESULTS AND DISCUSSION

All the antenna simulations are done using HFSS software. In conventional patch antennas TM_{01} mode is greater mode because of that two feed with different mode operates at two distinct frequencies. To activate dual-port diversity of patch antenna with hybrid feed network has been utilized. With top and bottom short circuited and the sides open-circuited, the patch of the antenna will work as a resonating cavity. At the resonant frequency antenna is excited because of that on the surface of patch strong current is set-up. In Figure 1 contact feed is used. Since it works as a connecting element and with the help of microstrip line the patch is feed by the RF power. The circular patch is having a four triangular slot on it.

As shown in Figure 1(a) four equilateral triangular slots are made on the patch with length as L_4 =16 mm which are placed symmetrically across the patch. This helps for achieving dual-band operation. The difference of the slots from the Centre of the patch is 7 mm. A driven hollow copper rod of radius R_3 and capacitive feed technique are used to make two mode resonates at various frequency range. Figure 2 shows simulated reflection coefficient of the proposed antenna structure of port 1 and port 2 which is used in various wireless applications. Port 1 has 2.2 GHz and 7.8 GHz similarly port 2 has 1.7 GHz and 11.6 GHz producing a dual-band response. Antenna has better response due to excitation of both broadside and conical mode is given separately in the proposed antenna design.

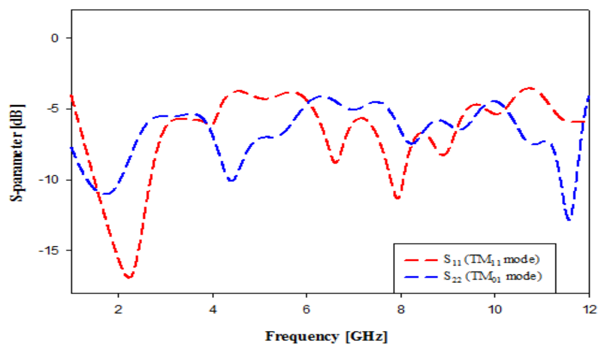


Figure 2: Simulated reflection coefficient of proposed antenna structure

Figure 3 illustrates the simulated S_{21} the response of the proposed antenna which has good isolation up to -22 dB between two ports of the antenna. It is achieved by using hybrid feed technique in the antenna design. Here S_{21} represents power transferred from Port 1 of the antenna to Port 2.

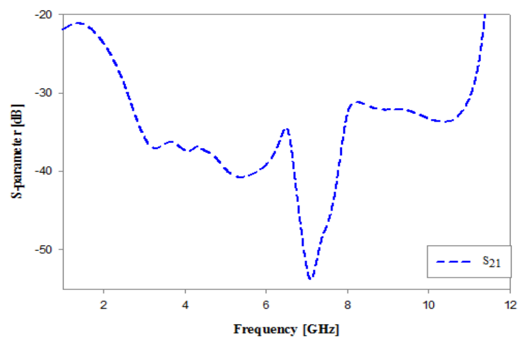


Figure 3: Simulated S_{21} parameter of proposed antenna structure

By modifying the dimensions of H-shaped slot and stub length L_1, matching of impedance as well as perfect bandwidth of TM_{11} mode at port 1 has achieved. Circular patch of size R_1 and thickness h of air-gap helps to determine the resonant frequencies of TM_{01} mode. The antenna parameters have been optimized to minimize the antenna dimension.

Simulated VSWR response of the antenna is given in Figure 4. For Port-1(TM_{11}) has VSWR of 1.33 and 1.75 for 2.2 GHz and 7.9 GHz respectively. For port-2 (TM_{01}) has VSWR of 1.77 and 1.59 for 1.7 GHz and 11.6 GHz respectively.

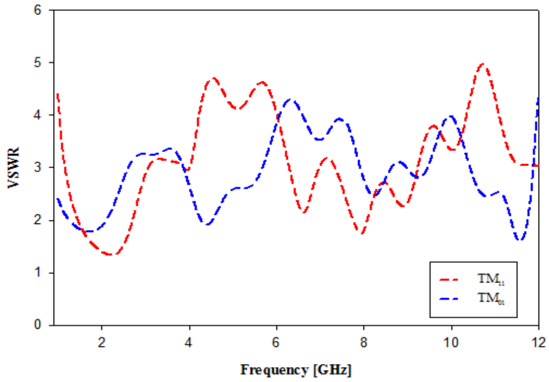


Figure 4: Simulated VSWR of proposed antenna structure

Simulations of all the antenna parameters are done by using HFSS V.14. The proposed antenna is fabricated and its prototype is shown in Figure 5.

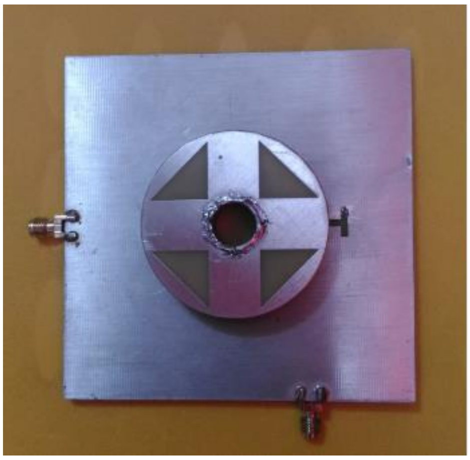
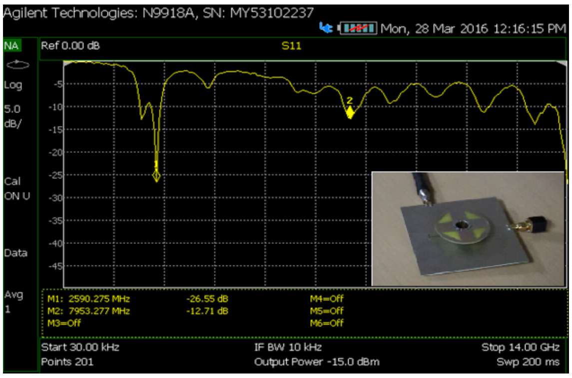


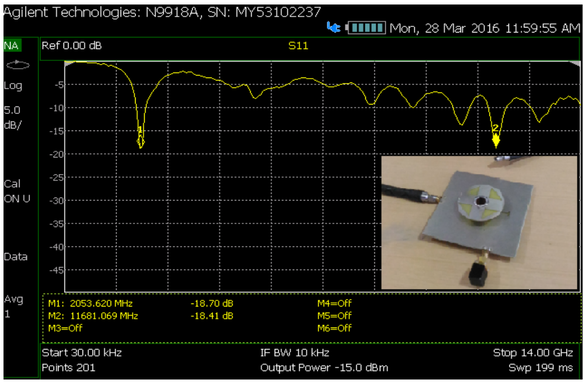
Figure 5: Photograph of the proposed antenna

To confirm the antenna simulated results, all the antenna characteristics are measured using Agilent vector network analyzer N9981A. Figure 6(a) represents measured reflection coefficient of proposed antenna for port 1 is resonating at 2.5 GHz and 7.9 GHz. Similarly, the port 2 resonates at 2 GHz and 11.68 GHz as shown in Figure 6(b).

From these results it is assured that simulated and measured results are nearly alike in both the modes.



(a)



(b)

Figure 6: Measured reflection coefficient of the proposed antenna (a) TM_{11} mode (b) TM_{01} mode

Figure 7 depicts the measured isolation up to -25 dB between two feeding ports. When port 1 is measured, termination of port 2 with 50 Ω load is done. Similarly, when port 2 is being measured, port 1 should be terminated using 50 Ω load.

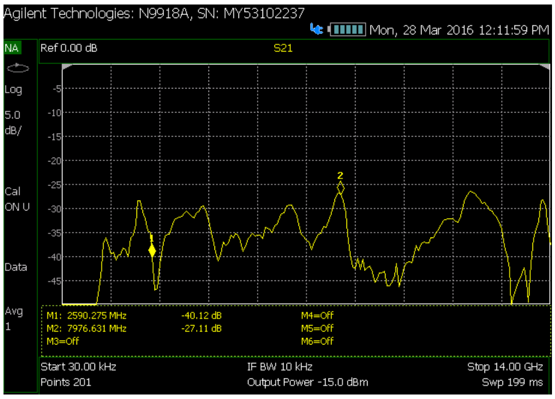
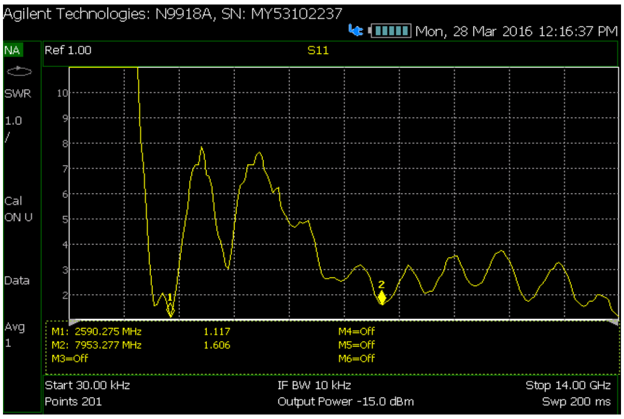


Figure 7: Measured S_{21} of the proposed antenna

Figure 8(a) and (b) shows the measured VSWR characteristics. In Port 1 has VSWR of 1.11 and 1.60 for TM_{11} mode at 2.5 GHz and 7.9 GHz. At Port 2 antenna has VSWR of 1.25 and 1.28 at 2 GHz and 11.6 GHz respectively. The proposed antenna has better VSWR performance which are less than 2 in both simulated and measured results.

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 21 (2017) pp. 11345-11349



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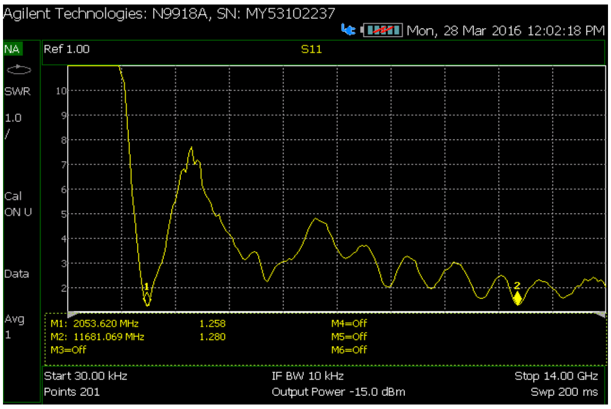
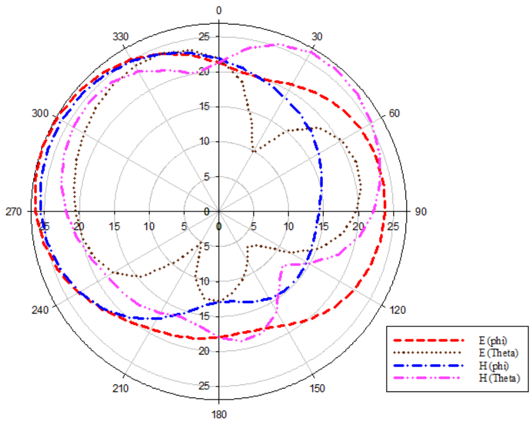


(b)

Figure 8: Measured VSWR of proposed antenna (a) TM_{11} (b) TM_{01}

Due to tolerance level in fabrication process and soldering effect there are slight difference among simulated and measured results of the proposed antenna. Figure 9 illustrates the E-plane and H-plane radiation pattern characteristics for TM_{11} at (a) 2.2 GHz and (b) 7.9 GHz. Antenna has omnidirectional shaped radiation performance in H-plane of both frequencies while E-plane has distorted shaped due to proximity feeding network.



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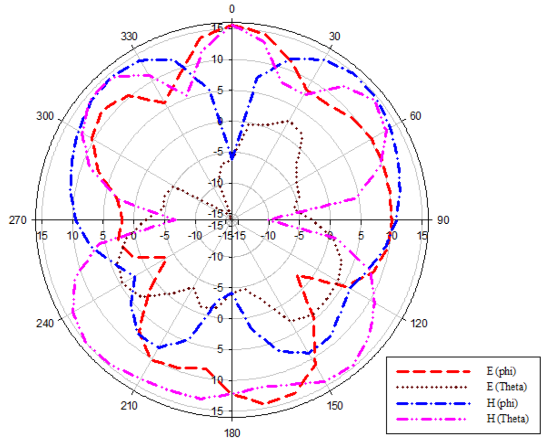
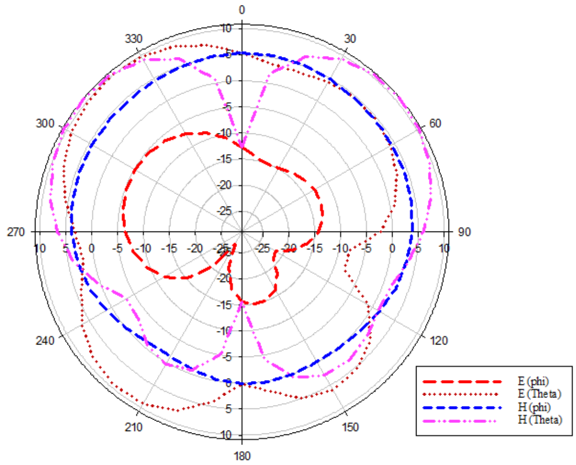


(b)

Figure 9: E-plane and H-plane radiation pattern of proposed antenna for TM_{11} mode (broadside radiation) (a) 2.2 GHz (b) 7.9 GHz



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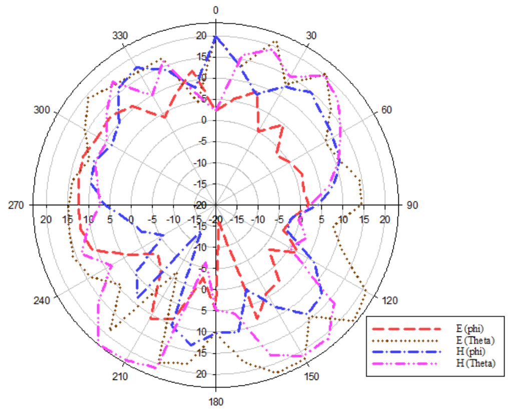

(b)

Figure 10.: E-plane and H-plane radiation pattern of proposed antenna for TM_{01} mode (conical radiation) (a) 1.7 GHz (b) 11.6 GHz

Similarly, Figure 10 (a) and (b) represents the E-plane and H-plane radiation pattern characteristics of conical mode for (a) 1.7 GHz and (b) 11.6 GHz. Antenna has good gain values in all the desired frequencies.

CONCLUSION

A dual-port patch antenna with polarization diversity and different radiation characteristics for dual-band operation has been presented. Proximity-coupling of H-shaped slot and TM_{11} mode gives the broadside radiation. A driven hollow copper rod and capacitive feed technique are used to obtain the resonant frequency of TM_{01} mode. A better isolation is achieved by exciting broadside mode and conical mode using hybrid-feed. The resonance frequencies of the proposed antenna can be used for wireless applications.

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