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RESEARCH PAPER

Modified CPW-fed rotated E-slot antenna for LTE/WiMAX applications

GEETANJALI SINGLA AND RAJESH KHANNA

In this paper, a rotated E-slot antenna with modified coplanar waveguide (CPW) feeding is presented to obtain broadband characteristics. The antenna comprises of a planar rectangular patch element embedded with E-slot rotated 90° anticlockwise on the radiating side. The CPW feed is modified by extending the ground plane throughout the substrate to surround the rectangular patch. This structure is capable of generating three separate resonant modes with good impedance matching. The antenna is designed on an FR4 substrate of 1.6 mm thickness, covering bands from 3.4 to 3.6 GHz for LTE and 3.4–3.694 GHz for worldwide interoperability for microwave access (WiMAX) systems. The proposed antenna provides good return loss S_{11} and impedance behavior.

Keywords: Antennas and propagation for wireless systems, Applications and standards (mobile, wireless, networks)

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I. INTRODUCTION

In the era of technological advancement, there has been a tremendous increase in the demand of small-sized high-performance multiband personal communication handsets capable of covering various standards developed in wireless communication simultaneously [1]. It has led to the research and studies of microstrip antennas as a viable solution to this interesting problem due to its advantages such as low-profile, conformability, low-fabrication cost, and ease of integration with feed networks [2].

The rapid developments of wireless communication systems, especially for WLAN, worldwide interoperability for microwave access (WiMAX), and long term evolution (LTE) applications, which cover all the bands of 2.4/5.2/5.8 GHz, 2.5/3.5/5.5 GHz, and 3.4/4.4 GHz, respectively, have aroused much interest in the research of multi band and broadband antennas [3]. In [4], the authors have referred to various papers pertaining to coplanar waveguide(CPW)-fed design configurations such as a monopole antenna fed with a meandered coplanar waveguide, CPW-fed tapered bent folded monopole antenna, printed monopole antenna with a trapezoid conductor-backed plane, CPW-fed monopole antenna with a cross-slot for WLAN operation, CPW-fed Koch-fractal slot antenna, dual-band annular-ring slot antenna, and to obtain broadband characteristics in antenna operation [5–10].

In this paper, we have combined two techniques i.e. modified CPW feed and slotting and applied them on the radiating rectangular patch in a different fashion to create multiple bands and widen the bandwidth of each band. The design of wideband microstrip patch antenna is presented in Section II. The results and discussion are given in Section III.

Department of Electronics and Communication Engineering, Thapar University, Patiala, Punjab, India. Phone: +91 9855482690
Corresponding author:
G. Singla
Email: geetanjalikapur@rediffmail.com

II. ANTENNA DESIGN

In the proposed design, the antenna patch is made of perfect electric conductor mounted on FR4 substrate with relative permittivity, $\varepsilon_r = 4.4$, tan delta = 0.027 at 2 GHz and height, $h = 1.6$ mm.

The antenna structure consists of a rectangular patch with E-slot in its center, rotated 90° anticlockwise. The geometry of

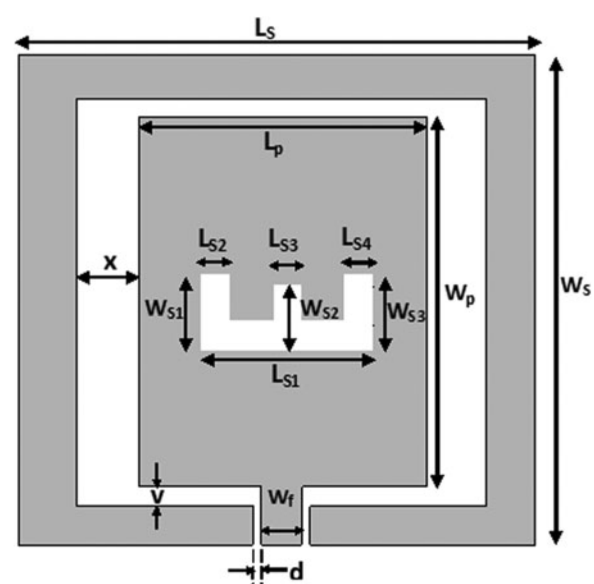

Fig. 1. Geometry of the antenna patch.

the antenna patch is depicted in Fig. 1, where L_p (length of patch) and W_p (width of patch) are connected at the end of the CPW feed line.

It has been noticed in the simulation that the operating bandwidth of the rotated E-shaped microstrip patch antenna is critically dependent on the length (L_p) and width (W_p) of the rectangular patch of the antenna. The optimization is done in terms of length and width of patch to obtain optimal band of operation for the WiMAX and LTE systems and good impedance matching at each resonating centre frequency. The final optimized geometric parameters of the proposed antenna are: $L_p = 43.75$ mm, $W_p = 51.95$ mm, substrate length $L_s = 90$ mm, and substrate width $W_s = 90$ mm. Four slots are etched in the radiating patch to control the current flow on the antenna surface across the targeted frequency bands. The optimized slot dimensions obtained are: slot length $L_{s1} = 24$ mm, $L_{s2} = 4$ mm, $L_{s3} = 4$ mm, and $L_{s4} = 4$ mm; slot width $w_{s1} = 12$ mm, $w_{s2} = 10$ mm, and $w_{s3} = 12$ mm.

A CPW transmission line is used for feeding the antenna. It consists of a signal strip of width $w_f = 4.94$ mm with a gap distance, $d = 0.175$ between the signal strip and the coplanar ground plane. Two equal finite ground planes are placed

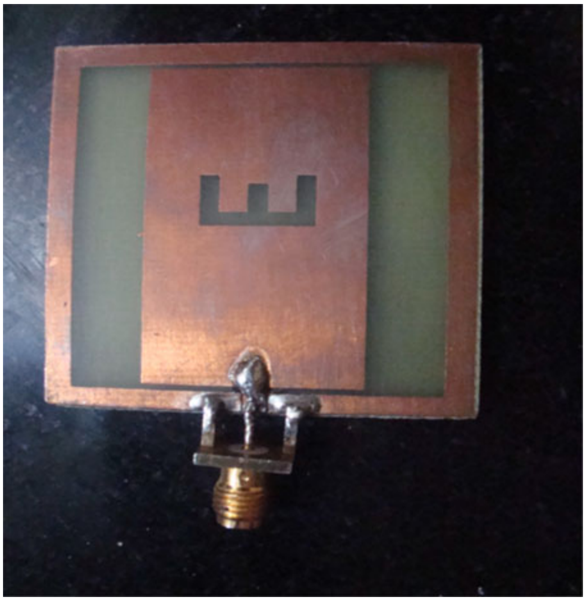

Fig. 2. Fabricated antenna structure.

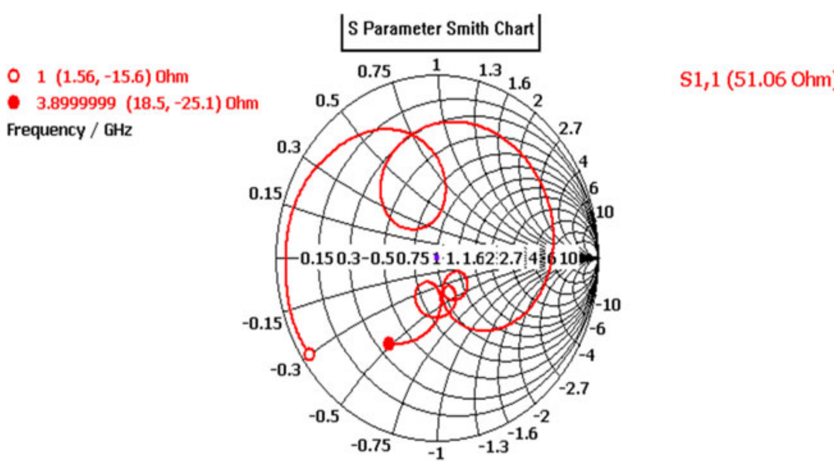

Fig. 3. Smith chart for impedance matching of the proposed antenna structure.

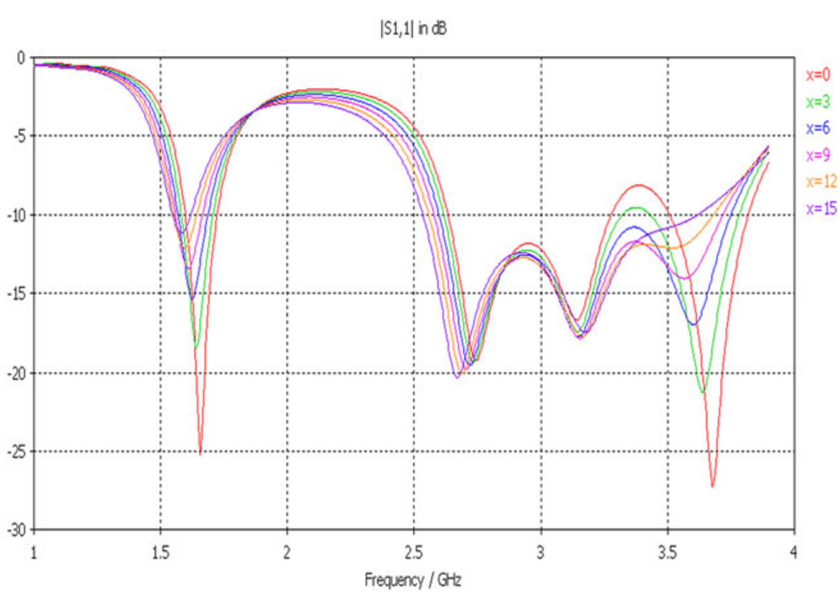

Fig. 4. Sweep results for variation of spacing between patch edge and CPW ground along *X*-axis.

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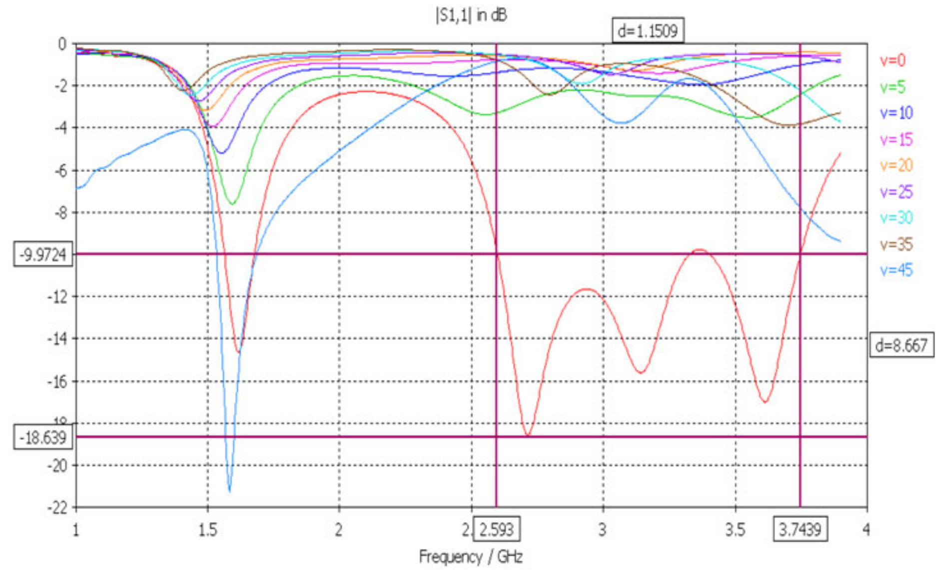
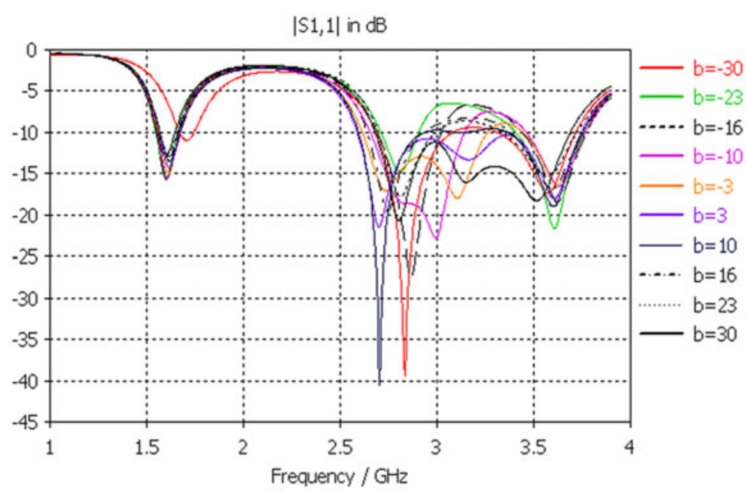


Fig. 5. Sweep results for variation of spacing between patch edge and CPW ground along +ve Y-axis.



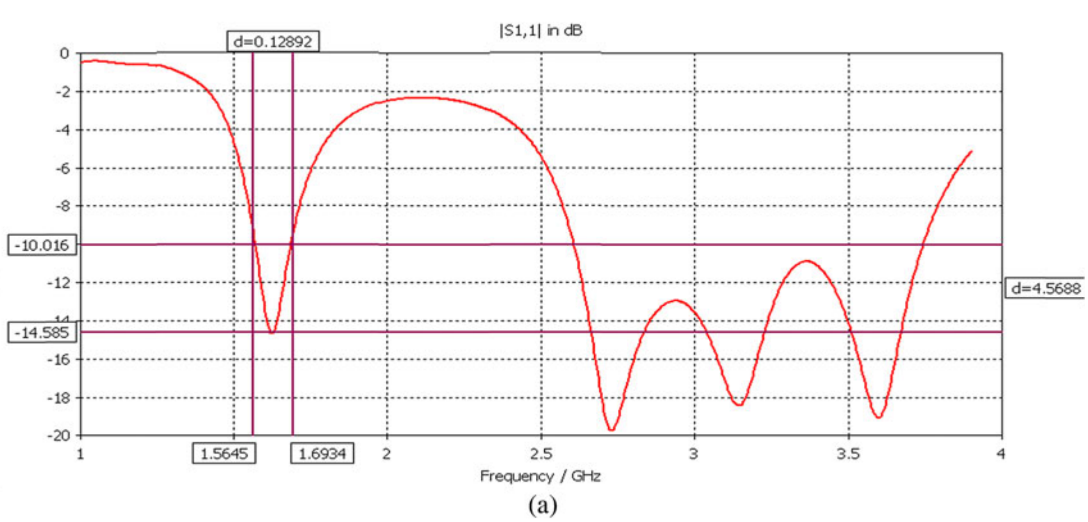


Fig. 7. (a) Return loss/impedance bandwidth for first band. (b) Return loss/impedance bandwidth for second band.

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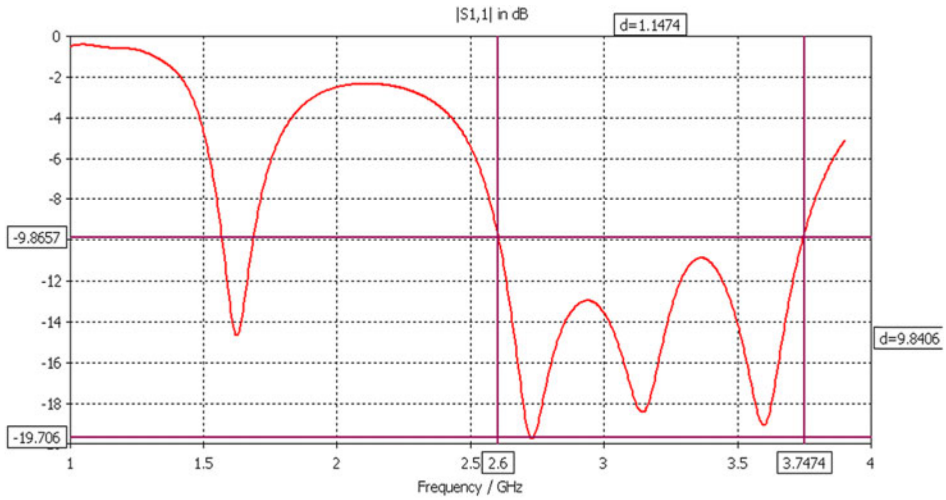
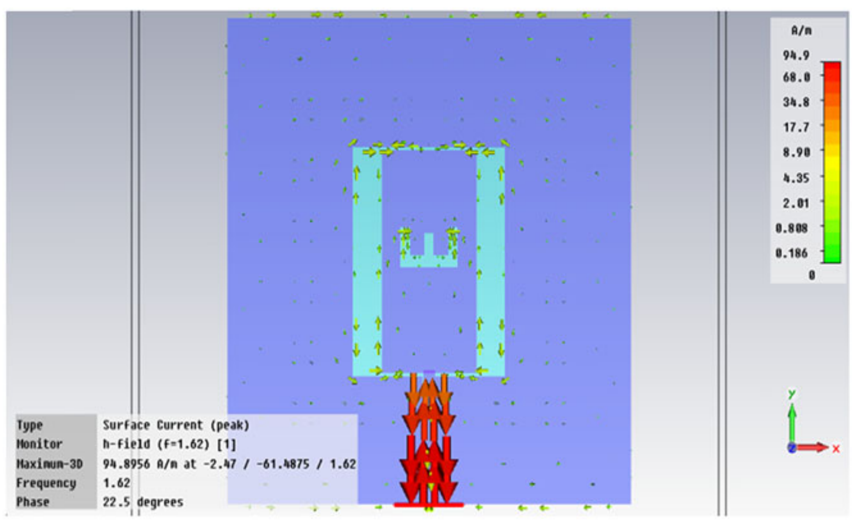
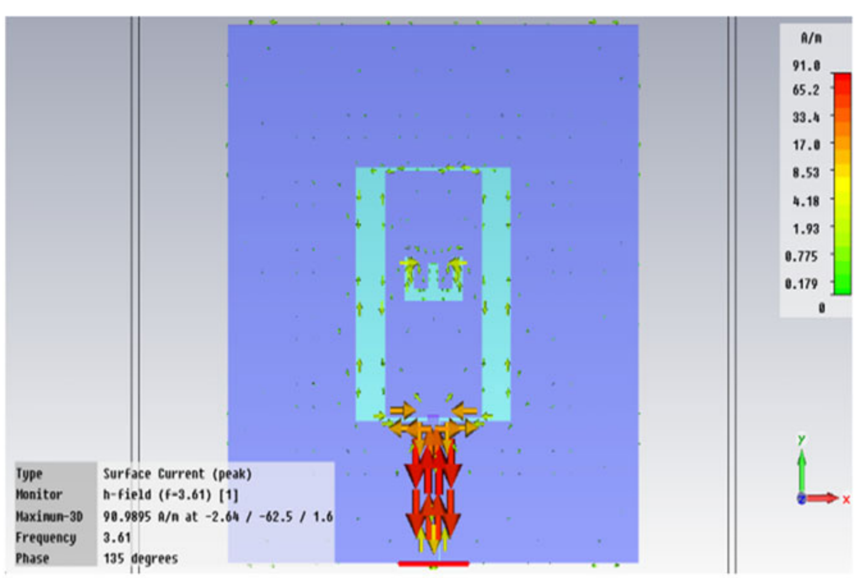


(b)

Fig. 7. (continued)



(a)



(b)

Fig. 8. Simulated current density on the surface of the antenna at (a) 1.62 GHz, (b) 3.61 GHz, (c) 2.71 GHz, and (d) 3.14 GHz.

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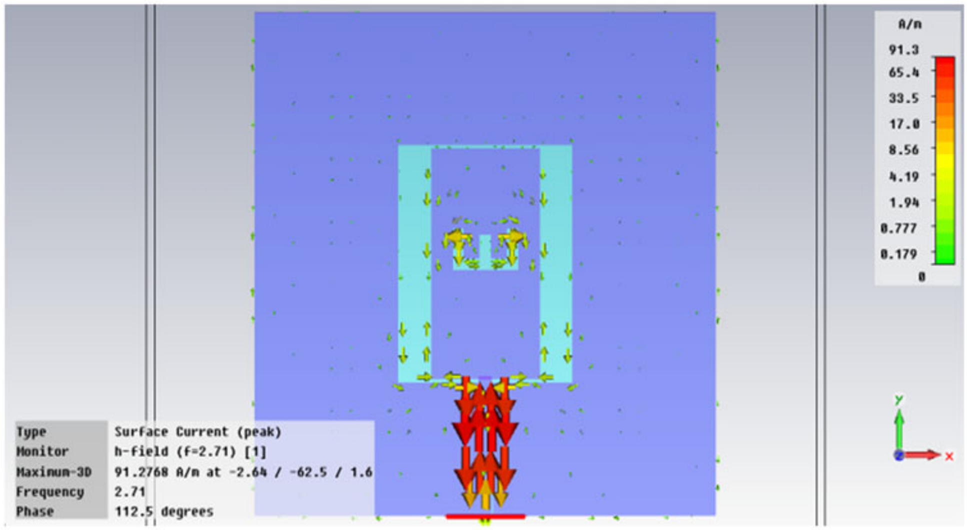
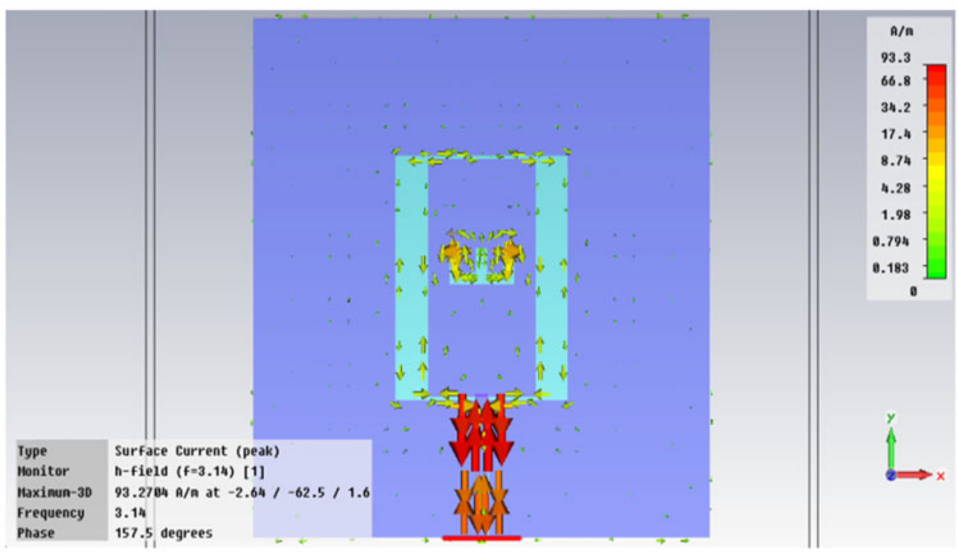


(c)



(d)

Fig. 8. (continued)

symmetrically on each side of the CPW feed-line to surround the rectangular patch. The fabricated design structure of the antenna is shown in Fig. 2. The width and position of the stripline feed determine the impedance matching of the antenna at a particular resonant frequency as shown by the smith chart in Fig. 3.

III. PARAMETRIC STUDY OF ANTENNA

Parametric study is investigated and it demonstrates that the following parameters influence the performance of the proposed antenna in terms of return loss, impedance bandwidth, gain, etc.

A) CPW ground plane structure

A CPW ground plane structure surrounds the rectangular patch on all sides in such a manner to create a spacing between the patch edge and the CPW ground referred to as "x" on X-axis and "v" on vertical i.e. Y-axis. Along the X-axis the initial value of the gap is fixed at 12 mm and sweep function is applied by varying x from 0 to 15 in steps of 3. It is observed that at $x = 0$, we get a triple band. When the value of x is increased it leads to merging of 2nd and 3rd band generating a broadband antenna, the best value being $x = 6$ or the total gap value of 18 mm for which the bandwidth is 1.15 GHz. The antenna responds symmetrically both along the positive and negative X-axis as shown in Fig. 4.

The vertical spacing "v" is also analyzed along Y-axis for broadbanding and multibanding characteristics. "v" is varied from 0 to 45 mm with step size of 5. Starting with the initial gap of 1 mm, it is observed that $v = 0$, i.e. the vertical gap value of 1 mm yields best results as shown in Fig. 5.

B) Slotting on radiating patch

The rectangular patch is slotted as shape of "E" rotated 90° anticlockwise and the effect of variation of the position and

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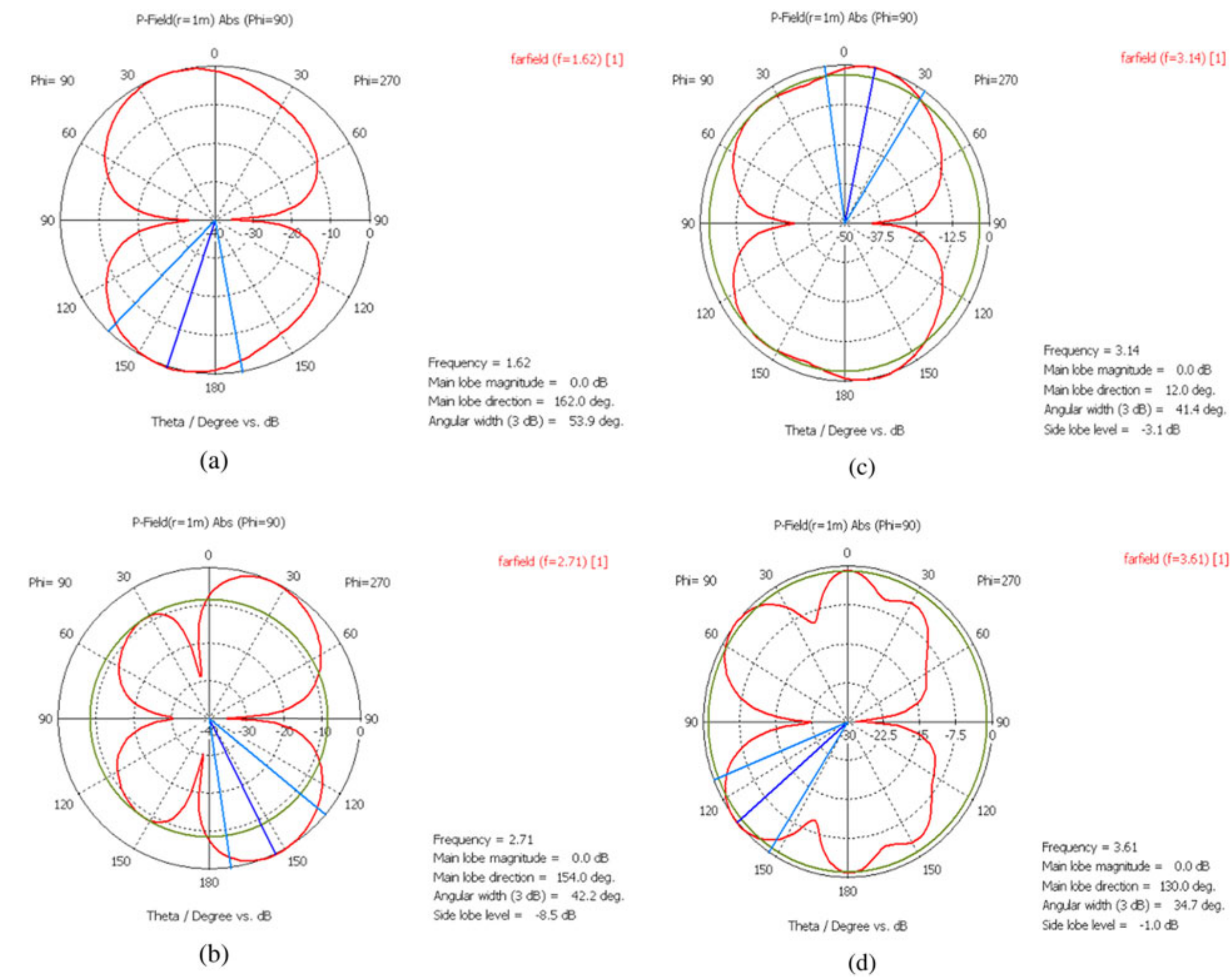

Fig. 9. Radiation pattern of the antenna at (a) 1.62 GHz, (b) 2.71 GHz, (c) 3.14 GHz, and (d) 3.61 GHz.

dimension of each slot on the bandwidth is studied and plotted in the return loss characteristics. A collective sweep is applied to all slots by a variable parameter *b*, which gives best bandwidth at value −16 mm as shown in Fig. 6. This value is in addition to the independent initial value for each slot which gives the optimized slot dimensions as: slot length $L_{s1} = 24$ mm, $L_{s2} = 4$ mm, $L_{s3} = 4$ mm, and $L_{s4} = 4$ mm; slot width $w_{s1} = 12$ mm, $w_{s2} = 10$ mm, and $w_{s3} = 12$ mm.

IV. RESULTS AND DISCUSSION

The optimized antenna results obtained after applying sweep to various design parameters are presented below.

A) Return loss

The return loss for the first band so obtained covering frequencies from 1.56 to 1.69 GHz is −14.6 dB and as that of second band in the frequency range from 2.6 to 3.75 GHz is −19.76 which is well below −10 dB level required for the antenna to operate efficiently (Figs 7(a) and 7(b)).

B) Current distribution and radiation pattern

The current density and radiation patterns are analyzed using CST MWS. With a series of simulations it is seen that the surface current on the patch region of the antenna around the edges cause resonance at 1.62 and 3.61 GHz (Figs 8(a) and 8(b)) and the E-slots contribute to the radiation at 2.71 and 3.14 GHz (Figs 8(c) and 8(d)).

The radiation pattern is plotted at the different resonances. Almost Omni-directional radiation patterns at the resonant bands are observed in Fig. 9(a–d).

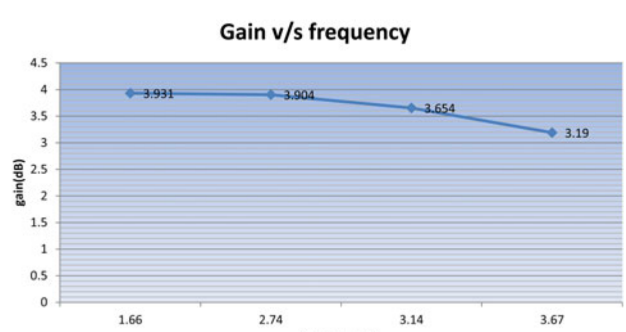

Fig. 10. Variation of gain with frequency.

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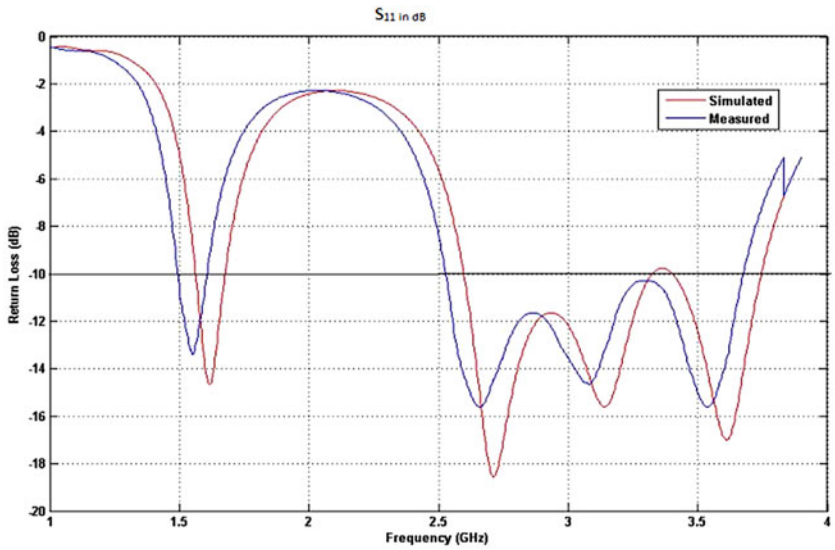

Fig. 11. Simulated and measured result.

The gain of the antenna is found to be constant throughout the resonant bands which make the antenna stable as seen from the graph plotted between gain versus frequency in Fig. 10.

The simulated and measured results are compared in Fig. 11 which verifies the designed structure in terms of return loss and impedance bandwidth obtained for different bands. The shift in resonant frequency between measured and simulated results is due small errors in fabricated structure.

V. CONCLUSION

In this paper, we present a design of a CPW-fed rotated E-slot microstrip patch antenna which is capable of operating at multiple bands with enhanced bandwidth at each band to be used in LTE/WiMAX applications. Measured results indicate that the antenna exhibits a good impedance bandwidth of 143.86 MHZ, 1.147 GHz at different bands. A return loss $S11$ parameter is found to be well below −10 dB, and considerable antenna gain with constant value is observed.

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Geetanjali Singla received her Masters in Electronics and Communication Engineering from BBSBEC, Fatehgarh Sahib in 2010 and is doing her Ph.D. degree from Thapar University. Presently, she is a lecturer at Thapar Polytechnic College, Patiala. Her main research interests are design and optimization of microstrip antenna, multiband and wideband antenna, and wireless communication networks. She has published many papers in journals and conferences on microstrip antenna and wireless communications networks.

Rajesh Khanna received his B.Sc. (Engg.) degree in ECE in 1988 from REC, Kurukshetra and M.E. degree in 1998 from IISc., Bangalore. He was with Hartron R&D center till 1993. Until 1999, he was in AIR as AS Engg. Presently, he is working as Professor and HOD in the ECED at Thapar University, Patiala. He has published 80 papers in National and International journal/Conferences. He has worth Rs 1.5 crore projects to his credit. His main research interest includes antennas, wireless communication, MIMO, and FFT.