Radiation Performance of a Compact CPW fed Modified Rectangular Patch Antenna

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Abstract: **This paper presents the design and performance of CPW fed rectangular microstrip patch antenna having V shaped notch and modified ground plane of overall size 36mm × 30 mm × 1.59 mm. The proposed antenna is simulated by applying CST Microwave studio simulator. This antenna has broad impedance bandwidth of 2.64 GHz (2.25 GHz – 4.90 GHz) with flat gain (close to 1.5dBi) in the desired frequency range. This antenna may be a useful tool for 2.4GHz (2.40-2.48GHz) WLAN communication band as well as for 2.3GHz (2.3-2.4GHz)/ 2.5GHz (2.5-2.69GHz)/ 3.3GHz (3.3-3.4GHz)/ 3.5GHz (3.5-3.6GHz)/ 3.7GHz (3.6GHz-3.8 GHz) Wi-MAX communication bands after further improvement in its gain.**

Keywords: **CPW fed; Microstrip Patch Antenna; Wi-MAX communication systems; radiation patterns; WLAN communication systems.**

1. INTRODUCTION

The Institute of Electrical and Electronic Engineers (IEEE) proposed three major WLAN band 802.11, 802.11 b and g, which perform in the 2.4-GHz frequency band, and 802.11a, which perform in the 5-GHz band. Recently, a high-speed 802.11 WLAN has been offered—the 802.11n WLAN, which operates in both the 2.4-GHz and 5-GHz bands. Wi-MAX stands for Worldwide Interoperability for Microwave Access and is proposed under the IEEE standards 802.16d and 802.16e (1-4). Communication systems are becoming compact in size and hence compact antennas with improved performance are required for these communication systems. Microstrip antennas may be proved very useful structures for these handsets, if their bandwidth performance improves. Size reduction and bandwidth enhancement are becoming major challenges these days. Conventional microstrip antennas have narrow bandwidth, low gain and operate at a single resonance frequency corresponding to their dominant mode. However they are planar structures and are compact in size, light in weight hence they can be put inside the handset without protruding out (5-7). Looking these advantages extensive efforts were made to improve their limitations (8-9). These antennas can be fed either through a coaxial cable or through strip line etched on the surface of antenna. Another way of feeding of patch antenna is coplanar wave guide. The coplanar waveguide (CPW) proposed by C. P. Wen in 1969 (10). Numerous advantages such as lesser radiation leakage and less dispersion have been obtained by feeding a patch with CPW.

For Wi-Fi and Wi-MAX communication bands, there are three ways to design antennas including (i) broadband/wideband or ultra wide band techniques, (ii) multiband techniques, and (iii) combining wideband and multiband techniques. For broadband operation, planar slot patch antenna such as rectangular slot, circular slot, bow tie slot and hexagonal slot are more promising due to their simple structure, easy to fabricate and broad impedance bandwidth characteristics. In order to achieve, the broadband performance of the microstrip antenna, some researchers have proposed a variety of antenna structure, slots, widened stub with metallic strip, Koch fractal slot in patch etc. with cpw feeding. K. Nithisopa et. al. designed CPW fed two slots patch antenna of impedance bandwidth 1.65GHz for 2.4GHz band (11). Chaimool et. al. proposed a new idea using widened stub with metallic strip in microstrip slot antenna and designed CPW fed patch antenna for WLAN and WI-MAX bands(12).D.D. Krishna et al designed triangular slot antenna for WLAN and WIMAX applications with Koch iteration technique for lowering the operating frequency(13).

In the present work, a CPW fed rectangular patch antenna with V shaped notch having modified ground plane is considered. This antenna is simulated in free space and the performance of this antenna is reported in this paper.

2. ANTENNA DESIGN AND ANALYSIS

In the first step of our work we designed a CPW fed conventional rectangular patch antenna having dimensions length L_p = 18.30 mm and width W_p = 12.20 mm. The overall size of antenna is 36mm x 30mm. These dimensions were selected so that designed antenna may resonate in the frequency band allocated for the lower band for Wi-MAX / UWB communication system. This selection of antenna dimensions is based on the computation work carried out through our own developed code based on cavity model based modal expansion technique. For designing the antenna the glass epoxy FR-4 substrate having relative permittivity $\varepsilon r = 4.4$, substrate height h = 1.59 mm and loss tangent = 0.025 is used. For feeding this antenna we have adopted strip line feed arrangement and used a quarter wave line of length F_L = 10.80mm and width F_w = 4.6mm. This line is attached with this patch to feed this antenna and connected with a 50 ohm cable through SMA connector. Planar antenna having inset feed arrangement requires more space for connector inside the handset while much smaller space for connector is required when strip line feed is applied.

Hence such an antenna may be put directly inside the casing of the handset. The gap 'g' between patch and ground is 1.80mm while the gap G_f between the strip line and ground plane is 0.20mm as shown in Fig 1. The length and width of ground plane are Lg = 12mm and Wg = 9mm respectively. The antenna performance is analyzed by using CST studio suite 2013 (14).

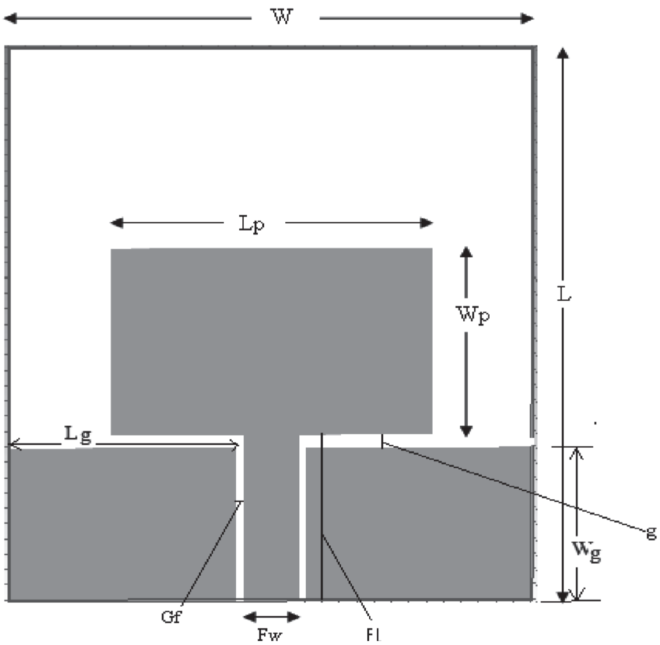

Fig 1: Front view of CPW fed conventional rectangular patch antenna

The simulated variation of reflection coefficient with frequency for considered rectangular patch antenna is shown in Fig. 2, which indicates that antenna is resonating effectively at a single frequency 3.40 GHz. The simulated impedance bandwidth of antenna is around 1.13GHz while maximum gain is close to 1.0dBi which is nearly constant in the frequency range of interest.

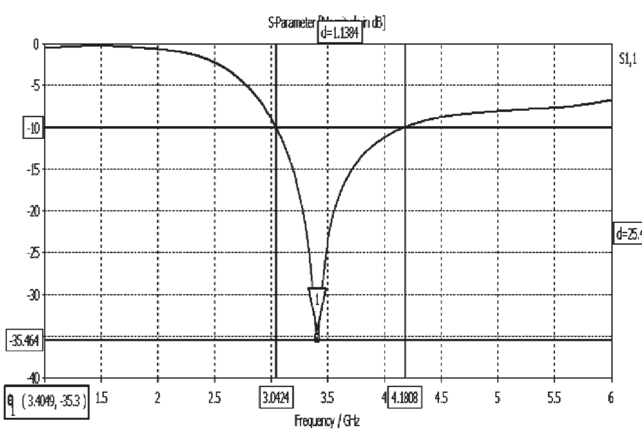

Fig 2: Simulated variation of reflection coefficient with frequency for CPW fed convential rectangular patch antenna

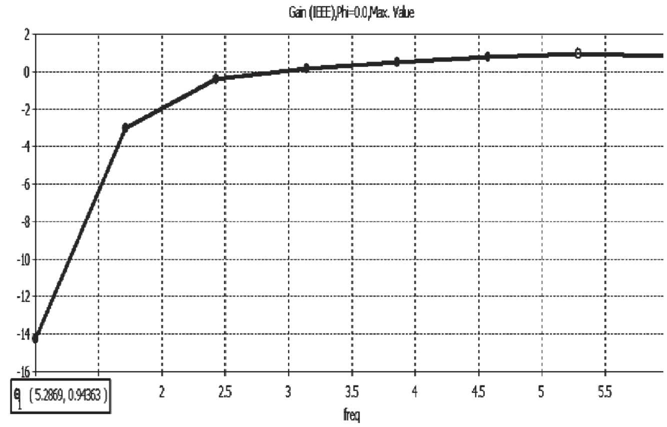

Fig 3: Simulated variation of gain of antenna with frequency

The simulation results provide little higher resonance frequency value than desired in lower band of Wi-Max communication systems and gain of this structure is quite low. Therefore this antenna needs improvement before it may be considered as a useful structure for modern communication systems.

In the next step, the impedance tuning was achieved by applying capacitive couplings. Using this technique, the patch antenna is modified. The gap (g) between patch and ground plane as well as gap (G_f) between feed line and ground plane are re-optimized by applying simulation software CST studio.

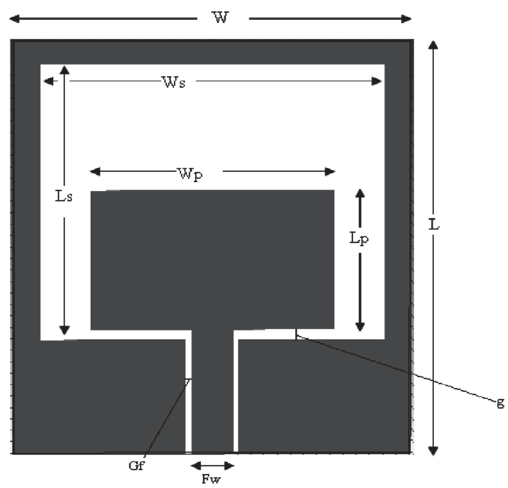

Fig 4: Front view of modified CPW fed rectangular patch antenna

Numerical values of the antenna dimensions are summarized in table 1. The simulation results shown in Fig. 5 indicate that antenna resonates effectively at two frequencies namely 2.45 GHz & 3.87 GHz and provides broad impedance bandwidth 2.52 GHz or 72% with respect to central frequency 3.47GHz. The maximum gain achieved here is close 1.32 dBi which is flat in entire frequency band as shown in figure 6.

TABLE I Optimized dimensions of proposed antenna

Dimension of proposed antenna	Value (in mm)
Length of the Substrate (L)	36mm
Width of the Substrate (W)	30mm
Length of the slot (Ls)	24mm
Width of the slot (Ws)	26mm
Length of the patch (Lp)	12.20mm
Width of the patch (Wp)	18.30mm
Length of the Feed line	10.80mm
Width of the feed line (Fw)	3.20mm
Gap between patch and ground(g)	0.80mm
Gap between feed line and ground(Gf)	0.40mm

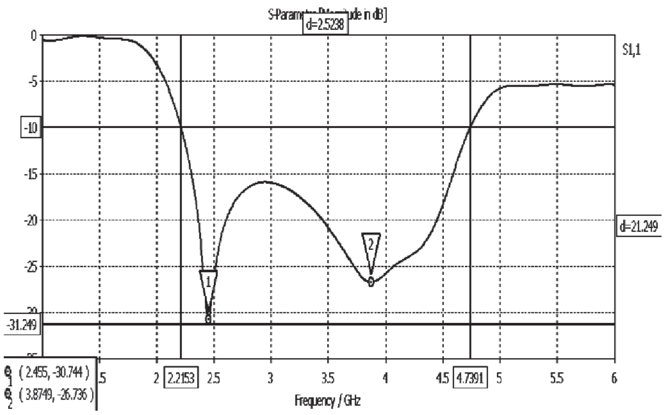

Fig 5: Simulated variation of reflection coefficient with frequency for CPW fed modified patch antenna

Simulated VSWR shown in figure 7 suggests good impedance matching between the feed line and antenna as the VSWR values at the two resonance frequencies are close to 1.0.

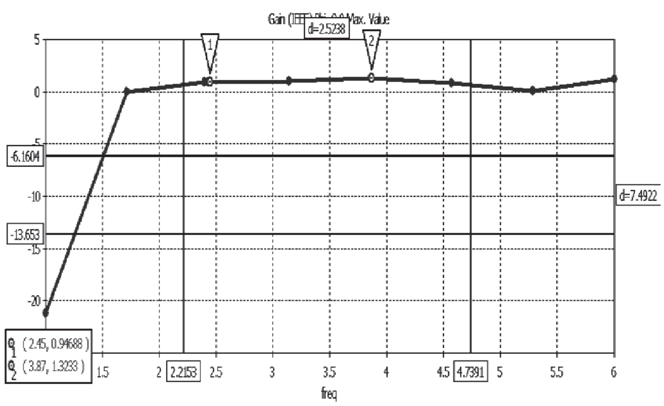

Fig 6: Simulated variation of gain of antenna with frequency

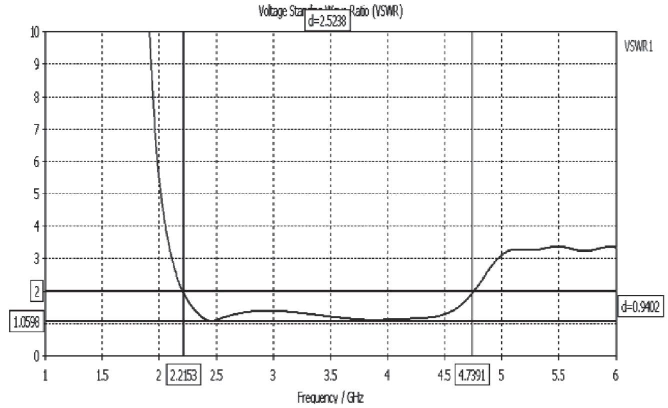

Fig 7: Simulated variation of VSWR with frequency for proposed CPW fed antenna

This antenna is further modified by introducing a V shaped notch of length 2.0 mm and height 14.0 mm in patch geometry as shown in Fig. 8. These dimensions are obtained after several optimizations. With introduction of proposed notch, the current in ground plane gets modified and that change in turn modifies the performance of antenna. For further improvement in antenna performance, an additional rectangular slot is introduced in ground plane having length 1.5mm and width 12mm. With these modifications; an additional resonance frequency close to 4.5 GHz is realized with further improvement in gain as well as in bandwidth values of antenna.

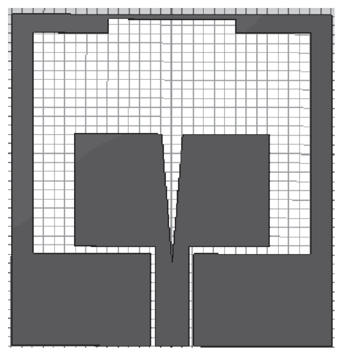

Fig 8: Front view of proposed CPW fed patch antenna

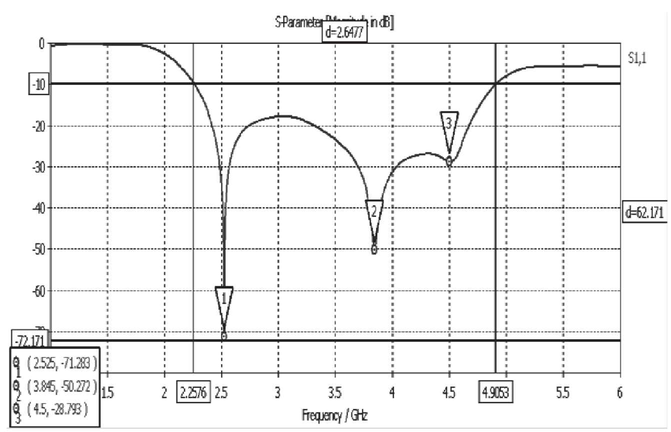

Fig 9: Simulated variation of reflection coefficient with frequency for cpw fed proposed antenna

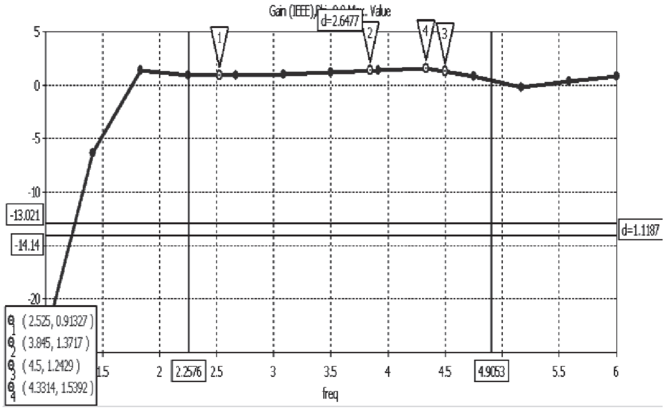

Fig 10: Simulated variation of gain with frequency

3. RESULT ANALYSIS

The proposed modified rectangular patch antenna provides much improved impedance bandwidth ~2.64GHz or 74% with respect to central frequency 3.58 GHz as shown in Fig.9. The proposed antenna resonates at three frequencies namely 2.55 GHz, 3.84 GHz and 4.49 GHz. The first frequency may be used for WLAN/Wi-Max communication systems while the second & third frequencies are suitable for Wi-MAX and lower band of UWB communication systems. The variation of gain of antenna as a function of frequency is shown in Fig. 10 which indicates that gain of antenna in the operating frequency range is almost flat. The maximum gain of antenna is close to 1.54 dBi at frequency 4.33GHz which is better than those realized in previous two cases.

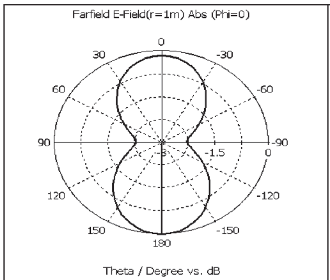

Fig 12a: E plane pattern at 2.52GHz

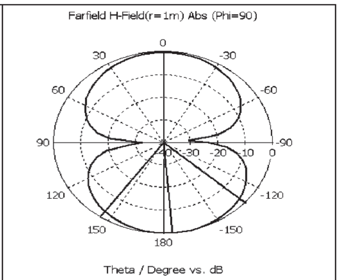

Fig 12b: H plane pattern at 2.52GHz

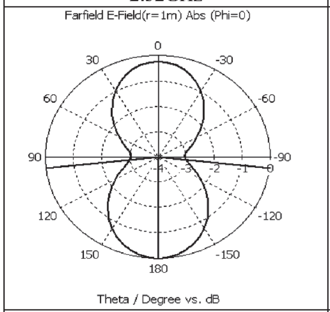

Fig 12c: E plane pattern at 3.84GHz

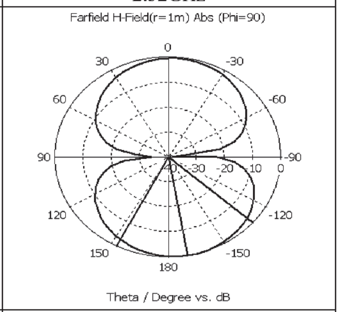

Fig 12d: H plane pattern at 3.84GHz

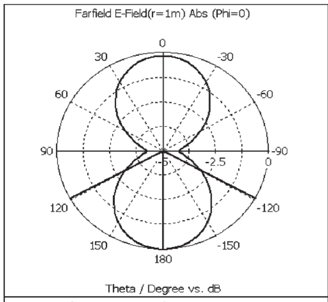

Fig 12e: E plane pattern at 4.5GHz

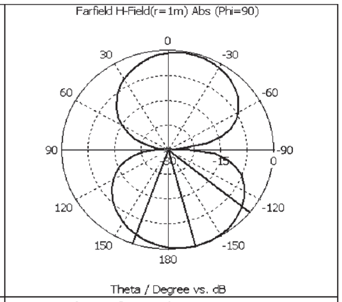

Fig 12f: H plane pattern at 4.5GHz

The two dimensional E and H plane radiation patterns of antenna at three resonant frequencies are shown in Figs. 12a – 12f. These figures indicate that antenna is radiating power both forward and back directions. However patterns are almost omni-directional, three figures have dumble shape which suggests that radiation pattern resembles with that of a dipole antenna. Simulated H plane radiation patterns are more directive than E-plane pattern at all three resonant frequencies.

4. CONCLUSIONS

Proposed CPW fed rectangular patch antenna with V shaped notch provides broader bandwidth (~2.64GHz), desired VSWR (2:1) and nearly flat gain in desired frequency range. The maximum gain of antenna is close to 1.54dBi. The effect of V notch and capacitive iteration has been successfully investigated. The antenna operates well at three resonance frequencies of operations. This antenna may be proved a useful structure for modern wireless communication systems including in WLAN, lower band of Wi-Max and lower band of UWB communication systems after little more improvement in its gain.

5. ACKNOWLEDGEMENT

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REFERENCES

[1] http://standards.ieee.org/getieee802/download/802.11-2007.pdf

[2] Edgar Danielyan, "IEEE 802.11," The Internet Protocol Journal, Volume 5, No. 1, March 2002.

[3] http://standards.ieee.org/getieee802/802.16.html

[4] Jarno Pinola and Kostas Pentikousis "Mobile WiMAX," The Internet Protocol Journal, Volume 11, No. 2 , June 2008

[5] Balanis C.A., “Antenna Theory Analysis and Design,” John Wiley & Sons, 2005.

[6] Bahl I.J. and Bhartia P., “Microstrip Antennas,” Artech House, Norwood ,1980.

[7] Chen Z.N and Chia M.Y.W., “Broadband Planar Antennas: Design and Application,” John Wiley & Sons , 2002.

[8] Kumar G. and Ray K.P, “A Broadband microstrip antenna,” Artech House, Norwood, 2003.

[9] Debatosh Guha, and Yahia M. M. Antar, "Microstrip and printed antennas new trends, techniques and applications," John Wiley & Sons ,2011.

[10] Wen C. P., "Coplanar waveguide: A surface strip transmission line suitable for nonreciprocal gyromagnetic device applications,"IEEE Transactions on Microwave Theory and Techniques,Vol.17,1087–1090, 1969.

[11] Nithisopa K., Nakasuwan J., Songthanapitak N., Anantrasirichai N. and Wakabayashi T., "Design CPW Fed Slot Antenna for Wideband Applications," PIERS ONLINE, VOL. 3, NO. 7,2007.

[12] Chaimool S, Akkaraekthalin P., Vivek V., " Dual-band CPW-fed slot antennas using loading metallic strips and a widened tuning stub," IEICE Transactions on Electronics, vol. E88-C, no.12, pp.2258-2265,December 2005.

[13] Krishna D. D., Gopikrishna M., Anandan C. K., Mohanan P., and Vasudevan K., "CPW-Fed Koch Fractal Slot Antenna for WLAN/WiMAX," IEEE antennas and wireless propagation letters, vol. 7, 2008.

[14] www.cst.com