W-Shaped slot Microstrip Patch Antenna for Multiband Applications

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Abstract* — A fictional design of a compact Micro-strip Patch antenna for multiband frequency has been depicted in this paper. It is a modified W shaped slot based miniature patch antenna having polyethylene substrate with dielectric constant of 3.5 and thickness of 1.5mm. The proposed scheme and feeding technique gives the antenna to operate at C band X band K_u band with moderated bandwidth. The antenna resonates at 6.63 GHz, 10.60 GHz and 12.93 GHz with directivity gain of 7.04 dBi, 8.60 dBi, and 8.77 dBi respectively. Compared with conventional Micro-strip antenna with the same dimension the performance of designed antenna improved. This paper also provides parametric study and performances, when antenna substrate is used as geo-textile (polypropylene ε_r =2.2) and paper (ε_r =3).

Keywords — *Network Protocols, Wireless Network, Mobile Network, Patch Antenna.*

I. INTRODUCTION

From primitive age of time, it always has been a constant challenge for human beings to be connected each other over a distance of place. Since then, evolution of communication is exaggerated from ancient drum signal to wireless communication technology. Today, wireless technologies have evolved tremendously that have comfort our daily, social, official and personal life in many different ways. Internet, Wimax, Mobile phone, radar, satellite etc opens a new horizon in communication system around the world where multi tasking activities are highly demanding for future generation. In last few decades it has been possible to integrate multiband features in wireless communication devices which made a multiband antenna attractive in many commercial applications that have single radiator with a capability to transmit and receive multiple frequencies. RF engineers already managed to develop multiband antenna such as printed inverted-F antennas (PIFAs) [1-6] and Sierpinski fractal antennas [7-9] but these antennas are complex in configuration which are difficult to design and fabricate. Recent years Microstrip Patch antenna has been widely used due to their outstanding advantages like low profile, conformal, cost effective, and light weight so researchers are investigating to mutiband characteristic as additional feature, but there is always a trade-off between the performance and design. Many conventional techniques are proposed passed years among them varactor diodes, PIN diodes, and switches are used to achieve mutiband application, but main drawback is the design need to have controlling turn ON/OFF switch for reconfigurable frequency operations and extra active component which makes the circuit more complicated[10-13].

In [14] U slot patch antenna was designed along with PIN diodes which are used as switch to turn ON and OFF the slots for different frequency bands. In [15] multiband is introduced by modifying the ground plane. There are many other methods to activate multiband application such as loading of shorting at different locations of MPA [16,17], Photonic Band Gap (PBG) structure configuration, but among all these slot technique is simple and straight forward way [18]. Many novel structures like Tapered Slot, Square Slot, U-Slot, T-Slot, V-Slot and many other shapes and structures were used by researchers reported in literatures [19-21]. The slots are generally incorporated to perturb the surface current path on the patch that generates local inductive effect which is responsible for multiband operation.

In current time there are many ranges of frequency bands for different communication system, they are allocated to services different purpose like civilian and military applications such as satellite communications, television, mobile systems, broadcast radio, vehicle collision avoidance system, global positioning system (GPS), radio-frequency identification (RFID), direction founding, radar systems, remote sensing, missile guidance, surveillance systems. These applications and devices mainly operate in C, X and Ku band which is allocated in the microwave radio region of the electromagnetic spectrum.

II. ANTENNA DESIGN

The geometry and layout of the proposed electrically small rectangular Micro-strip Patch antenna is illustrated in Figure 1 and 2 and summaries in Table I. The rectangular Micro-strip patch antenna (RMPA) is constructed based on the standard designing procedure. The length and width of the antenna are determined by following equation.

$$W = \frac{v_o}{2 f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

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

$$\Delta L = 0.421h\frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \quad (3)$$

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_{eff}}\sqrt{\mu_o \varepsilon_o}} - 2\Delta L \quad (4)$$

here W is the width of the patch, v_o is the speed of light in a vacuum, ε_r is the dielectric constant of the substrate, f_r is the target frequency, ε_{eff} is the effective dielectric constant of the material, ΔL represents the extension in length caused by the fringing effect, h is the thickness of the substrate and L is the length of the patch.

The parameters are calculated mathematically and then simulated in the software. The proposed antenna has square patch dimension of (WxL) 13mm x 13mm with modified W-shaped slot on it. The radiating patch is printed on the with low dielectric polymer weft yarn having relative permittivity of 3.52 and thickness of 1.5mm respectively. The overall dimension structure of proposed antenna is demonstrated where l_1 = 3mm, l_2 = 3mm, l_3 = 1mm, l_4 = 2mm, l_5 = 3mm, l_6 = 2mm, w_1 = 2mm, w_2 = 4mm, w_3 = 4mm, w_4 = 3mm, w_5 = 8mm, w_6=6mm. The size of the ground plane is 22mm x 22mm and the radiating patch fed by coaxial probe at the position shown in the figure.

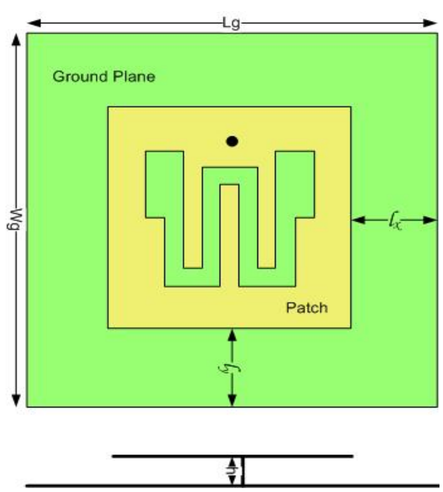

Fig. 1 Geometry of the proposed microstrip patch antenna

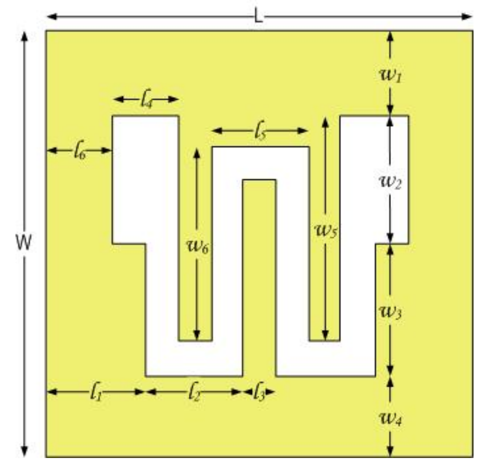

Fig. 2 Different dimensions of the proposed patch antenna

TABLE I. DIMENSIONS OF PROPOSED ANTENNA

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
l_1	3	w_2	4
l_2	3	w_3	4
l_3	1	w_4	3
l_4	2	w_5	8
l_5	3	w_6	6
l_6	2	L,W	13
w_1	2	Lg, Wg	22

III. RESULTS AND DISCUSSIONS

The performance of the proposed antenna is analyzed by using commercially available IE3D software which has Fast EM Design Kit for real-time full-wave EM tuning, optimization and synthesis and help to get precise result for mutiband. The proposed antenna has been designed on the conventional RMPA, whose length and width of the patch dimension are equal. Figure 3 represents the return loss versus frequency curve of RMPA. The antenna operates at 13.43 GHz having return loss of -13.47dB. The corresponding 10 dB return loss bandwidth of the centre frequency is 396 MHz.

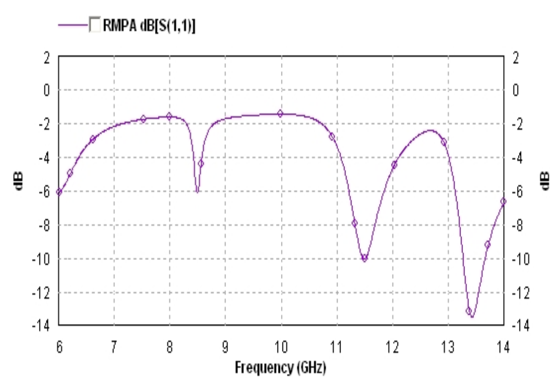

Fig. 3 Reflection coefficient (S_{11}) of RMPA

Figure 4 illustrates the result of the return loss of the proposed patch antenna. It is observed that resonant frequencies appeared in range of (6-14) GHz which are 6.63 GHz under C band, 10.60 GHz under X band and 12.93GHz under Ku with return loss of -45 dB, -18.5 dB and -28 dB respectively. The bandwidth of resonant frequencies is noticed after -10 dB critically which are typically about 225 MHz, 300MHz, and 415 MHz respectively.

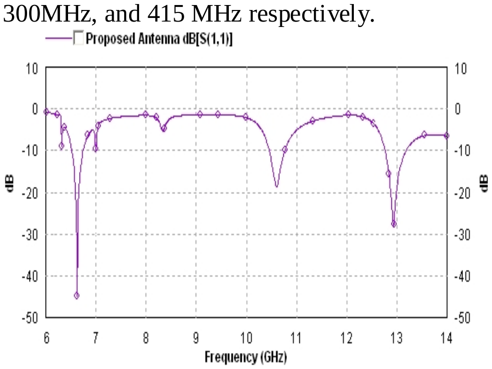

Fig. 4 Reflection Coefficient (S_{11}) of proposed antenna

Directivity is a measure of how focused and intense the radiation pattern is, of the antenna. For the proposed antenna at operating frequencies the directivities are 7.04 dBi, 8.6 dBi and 8.7 dBi in Figure 5, 6 and 7 respectively. The figures are shown for the elevation pattern from φ = 0 and φ = 90 degrees.

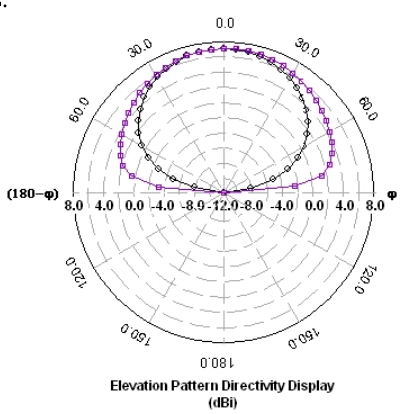

Fig. 5 Directivity of proposed antenna at 6.63 GHz

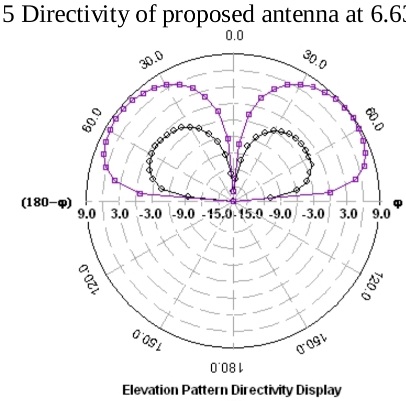

Fig. 6 Directivity of proposed antenna at 10.60 GHz

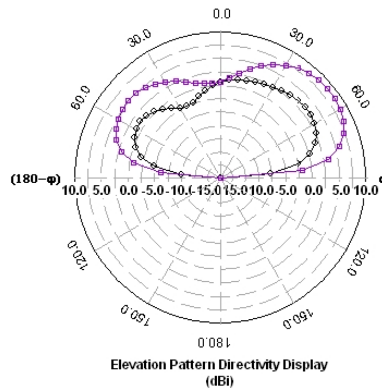

Fig. 7 Directivity of proposed antenna at 12.93 GHz

A. Comparison of RMPA and Proposed Antenna

Figure 8 shows the comparison between RMPA and proposed W-slotted MPA under 6 GHz to 14 GHz. RMPA has been design with same dimension of length and width and probe feeding point of proposed antenna. It is cleared that proposed antenna shows better performance in antenna characteristic. The RMPA operates at only Ku band whereas proposed antenna resonates at C, X and Ku band. The W shape slot technique provides the ability to operate in multiband application. The proposed antenna has radiation efficiency 73%, 46%, and 25% at operating frequencies respectively with reasonable antenna gain.

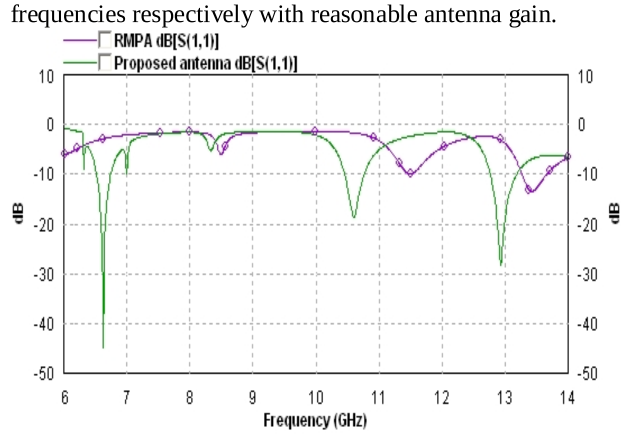

Fig. 8 Reflection Coefficient of Proposed antenna and RMPA

B. Parametric Study

The study has been made by varying the variable l_1, l_6 of the proposed patch from both sides. The variables are increased or decreased by 1mm of the W shape slot. The performance of the antenna for every case has been shown in the figure 9 and 10. When the variables of the slot are decreased towards the edge of the patch, the operating frequency of the X band shifted to left with impair return loss, Ku band operating frequency slightly shifted to left with better return loss enhancement and C band operating frequency remain same with poor return loss shown in Figure 9. When the variable of the slot are increased into the slot, the operating frequency has been shifted to the right with gradual improvement in return loss under X band and operating frequency of Ku band has also shifted to the right but gradually degraded in return loss shown in Figure 10.

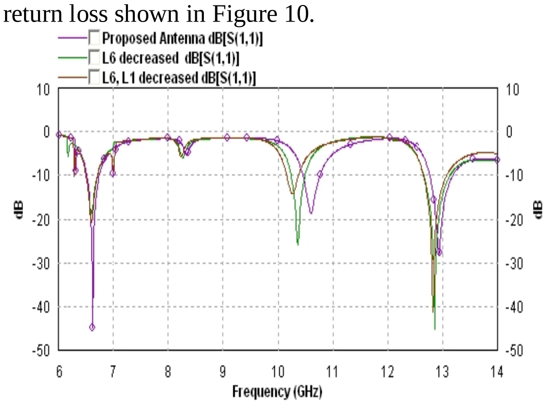

Fig. 9 Parametric study when l_6 and l_1 are decreased by 1 mm

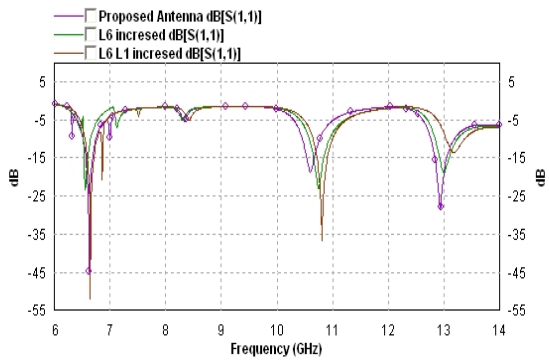

Fig. 10 Parametric study when l_6 and l_1 are increased by 1 mm

IV. Conclusions

In this paper, electrically small a multiband W slot shaped Micro-strip patch antenna is presented for wireless communication system especially for military spectrum (X band). Resonant frequencies are occurred in C, X, and Ku band with satisfactory gain of 5.7 dBi, 5.2 dBi and 2.5 dBi respectively and overall average gain of 4.5 dBi. The proposed antenna is thin and compact with low dielectric constant which auspicious feature for worldwide portability. Polypropylene and paper is also introduced for wearable geo textile purpose. Table 1 represent parametric study and overview of antenna characteristic in term of substrate various where for the both substrate it operates in X band frequency range.

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