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DESIGN OF NOVEL PATCH ANTENNA FOR 3.8GHz UAV WI-MAX APPLICATIONS

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Abstract

Antenna plays vital role in the development of Unmanned Aerial Vehicles (UAV) in aerospace technology. In this paper, a novel patch antenna for 3.8GHz UAV Wi-MAX application is presented. The proposed antenna has novel fork shaped radiating patch along with modified ground plane with 20×16mm² smallest dimension. The proposed antenna developed on the FR4 substrate with dielectric permittivity of 4.4 and height of the substrate is 1.6mm and loss tangent of 0.002 to achieve lower return loss possible. The proposed antenna simulated in an integral based solver simulation software called CST Microwave studio v2019 and obtained results such as Return loss -26dB with Bandwidth of 400 MHz, VSWR of 1.2, gain of 1.78dBi, Efficiency of 92%. This proposed antenna suitable for UAV Wi-MAX applications which uses 3.8GHz resonant frequency.

Keywords:

UAV, Wi-MAX, Patch Antenna, Modified Ground

1. INTRODUCTION

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot onboard. UAVs are a component of an unmanned aircraft system (UAS); which includes UAV, a ground-based controller, and a system of communications between the two consists of an antenna which decides the range for which an UAV can cover. Worldwide interoperability for Microwave Access network (WiMAX) as a suitable technology for drone communications in this UAV applications. A patch antenna is a type of radio antenna with a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane [1].

Therefore, this paper focuses on designing a novel antenna with the improved performances for the use of UAV Wi-MAX applications.

The software used in this work is CST Microwave studio v2019. CST microwave studio is an electromagnetic field simulation software which is based on finite integration technique and for analysis of patch antennas time domain solver used. CST MWS enables the fast and accurate analysis of high frequency (HF) devices such as antennas, filters, couplers, planar and multi-layer structures and SI and EMC effects. Exceptionally user friendly, CST MWS quickly gives you an insight into the EM behavior of your high frequency designs [16]. This CST microwave studio selected based on its user interface, which is very simple and has the capability of simulating complex structures. The proposed antenna has a novel fork shaped radiating patch in the top and modified ground plane at the bottom for resonating in 3.8GHz frequency.

The organization of this paper includes the introduction section as first part followed by the literature review and design methodology followed in the progress of the proposed antenna and the next section consists of results and discussion section and finally conclusion and future works completes the paper.

2. LITERATURE REVIEW

The literature review consists of the basics of micro patch antennas [1-3]. In [4], an SRR based metamaterial antenna for 4G WiMAX applications is discussed. In [5], a novel patch antenna for 2.4GHz WLAN applications is presented. In [6] Metamaterial based antenna for 5.5GHz Wi-Max applications presented. Analysis and design of a 3.5GHz patch antenna for WiMAX applications presented in [7]. Asymmetric CPW-fed SRR patch antenna for WLAN/WiMAX applications discussed in [8]. A wideband antenna with the defected ground plane for WLAN/WiMAX applications presented in [9]. In [10] Design of a compact U-shaped slot triple-band antenna for WLAN/WiMAX application is presented. In [11], a CPW fed trident shaped antenna for WiMAX/WLAN Application is presented. In [12], a compact Audi-shaped slotted multiband antenna for WiMAX/WLAN/X-band application is presented. In [13], a miniaturized UWB antenna with dual-band rejection of WLAN/WiMAX using slotted EBG structure is discussed. In [14] 3D-printed circular array for WiMAX base station application is discussed.

Different antennas available in literature for huge coverage area with larger size in the literature. The need of small antennas for shorter coverage area still exists and hence in this paper a novel patch antenna is presented for operating 3.8GHz resonant frequency UAV Wi-MAX applications.

3. ANTENNA DESIGN

The proposed antenna shown in Fig.1. The length and width of the regular patch antenna obtained from [1] is provided below.

Calculation of width (W):

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{C}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

where,

C is the free space velocity of light.

ε_r is the dielectric constant of substrate.

The effective dielectric constant of the microstrip patch antenna is given by,

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

The actual length of the patch (L):

$$L = L_{eff} - 2\Delta L \quad (3)$$

where

$$L_{eff} = \frac{C}{2 f_r \sqrt{\varepsilon_{eff}}} \quad (4)$$

Calculation of length extension:

$$\frac{\Delta L}{h} = 0.412 \frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \quad (5)$$

Calculation of VSWR (S):

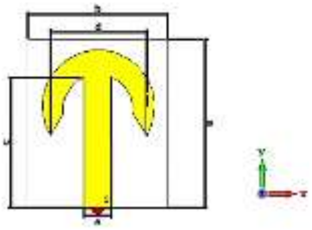
$$S = \frac{1+|\Gamma|}{1-|\Gamma|} \quad (6)$$

where, $|\Gamma|$= Reflection coefficient

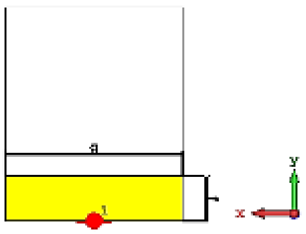
Calculation Bandwidth (BW):

$$BW = \frac{VSWR - 1}{Q\sqrt{VSWR}} \quad (7)$$

From the Eq.(1)-Eq.(7) for 3.5GHz resonant frequency the length and width of the patch found are, 25.59mm width and 19.54mm length from several iterations the overall dimensions were reduced to achieve size reduction to smallest possible parameters and the overall dimension of the proposed antenna consists of length *a* which is 20mm and width *b* is 16mm dimension. The Fig.1(a) shows the front view of the proposed antenna which consists of novel fork shaped radiating structure which obtained from modifying the normal circular patch and the slot introduced in the center of the patch is responsible for the generation of the resonating frequency 3.8GHz.



(a)



(b)

Fig.1. Proposed Novel Patch Antenna (a) Front View (b) Back View

The Fig.1(b) shows the back view of the proposed antenna which consists of modified ground structure which is responsible for the impedance matching. The dimensions of the antenna finalized after several iterations to meet the requirements of the Wi-MAX standards. The proposed antenna developed on FR4 Substrate with permittivity of 4.3mm and thickness 1.6mm. The patch designed in copper material having electrical conductivity of $5.8e^7$ with a thickness of 0.035mm.

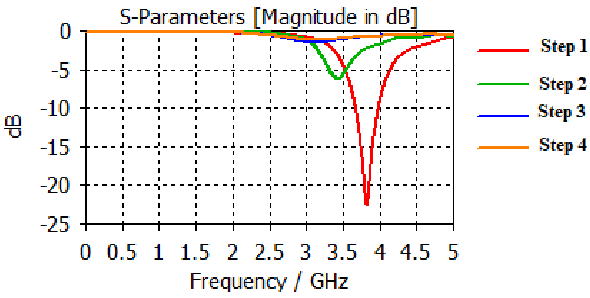


Fig.2. Variation of Return loss

The variation of return loss observed during the simulation process for finalizing the modified ground plane dimension. From the variation of return loss plot observed that the resonant frequency 3.8GHz obtained after the circular patch altered as fork shaped radiating element and the modified ground plane. The Table.1 shows the parameters used in the dimensions of the proposed antenna.

Table.1. Dimensions of the proposed antenna

Parameter	Part	Dimension (mm)
a	Substrate Length	20
b	Substrate Width	16
c	Feedline Length	15
d	Patch Width	11.5
e	Feedline Width	3
f	Ground Length	4
g	Ground Width	16

4. RESULTS AND DISCUSSION

In this section the results and discussion presented. The design and simulation done using CST microwave studio v2019 and its results such as return loss, VSWR, farfield radiation, surface current, gain and efficiency discussed below.

4.1 RETURN LOSS

Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line. The minimum return loss at 3.8GHz is -26dB for the proposed antenna shown in Fig.3. The -10dB Bandwidth obtained at 3.8GHz is 400MHz.

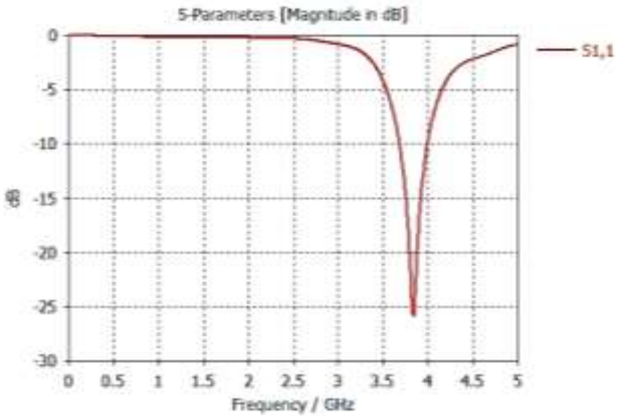


Fig.3. Return loss

4.2 VSWR

VSWR stands for Voltage Standing Wave Ratio, also referred to as Standing Wave Ratio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. The minimum VSWR (Voltage Standing Wave Ratio) obtained at 3.8GHz is 1.2 for the proposed antenna which given in Fig.4. The VSWR value must be from 1 to 1.5 for the perfect antenna and the proposed design achieves the value of 1.2 is closer to the perfect value.

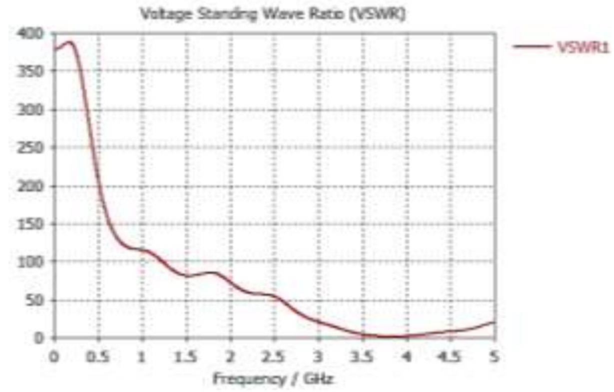
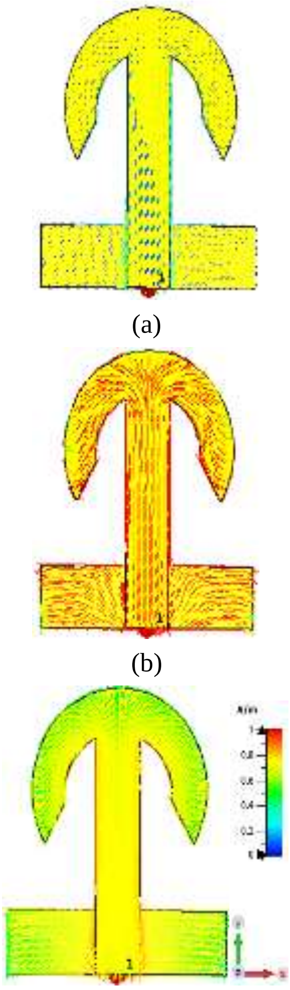


Fig.4. VSWR

4.3 SURFACE CURRENT DISTRIBUTION

Surface current distribution is a useful tool for analyzing the performance of the antenna design. The Fig.5 shows the surface current distribution obtained at 2GHz, 3.8GHz and 5GHz frequencies at resonant frequency 3.8GHz the maximum current distribution observed at the center of the radiating patch which has modified circular patch structure on the proposed antenna. The current flow starts from the feeding point equally distributed over the radiating patch and the modified ground region observed at the resonant frequency 3.8GHz.



(a)

(b)

(c)

Fig.5. Surface Current Distribution (a) at 2GHz (b) at 3.8GHz (c) at 5GHz

It is inferred from the Fig.5(a) that the variation in intensity of surface current at the feed line started to get increase at initial frequency of 2GHz and from the Fig.5(b) denotes the resonant frequency at 3.8GHz where the surface current intensity is high which represented by the red arrows clearly shows the designed patch antenna performs exactly at the resonant frequency 3.5GHz then at higher frequency of 5GHz the surface current intensity starts to decrease which is shown at Fig.5(c).

4.4 FARFIELD ANALYSIS

The 3D pattern in Fig.6 shows the distribution of the power radiated by an antenna as a function of the direction away from the antenna. The maximum gain obtained at 3.8GHz is 1.78dBi. It is inferred from the Fig.6. The proposed antenna has achieved better omnidirectional radiation pattern at the resonant frequency which is shown as red region around the antenna.

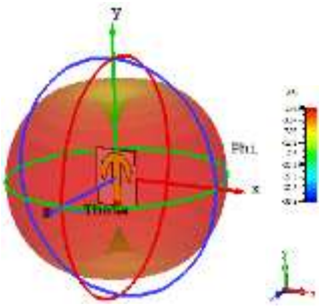


Fig.6. Farfield at 3.8GHz

4.5 EFFICIENCY

The maximum radiation efficiency obtained at 3.8GHz 83% and the total efficiency from 0 to 5GHz frequency range is 92% for the proposed antenna. It is inferred from the Fig.7 is that the proposed antenna achieved maximum efficiency at required resonant frequency.

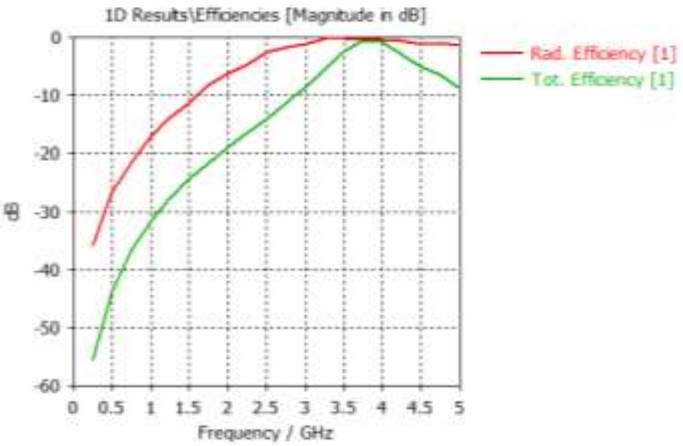
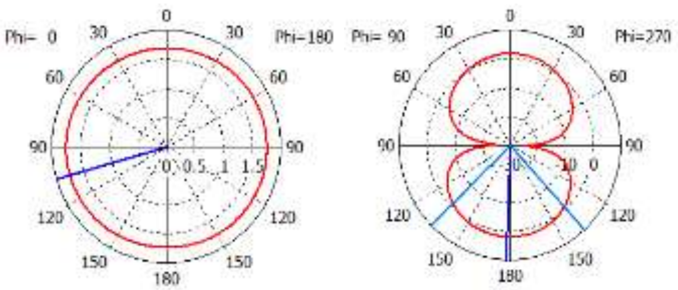


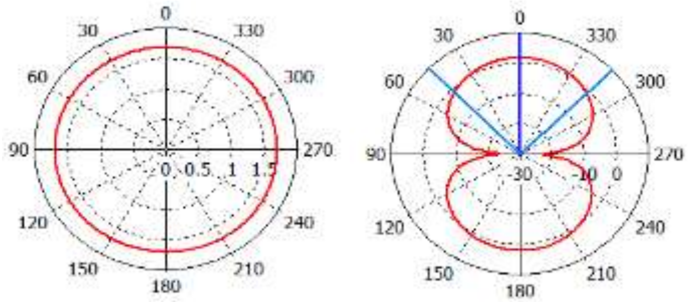
Fig.7. Efficiency

4.6 2D RADIATION PATTERNS

The proposed patch antenna achieves radiation patterns close to omnidirectional pattern at the resonant frequency 3.8GHz is shown in Fig.8(a) and Fig.8(c) are circular in shape and Fig.8(b) and Fig.8(d) are donut-shaped patterns which clearly shows that the proposed antenna performs omnidirectional pattern at resonant frequency.



(a) (b)



(c) (d)

Fig.8. Radiation Patterns (a) at Phi = 0° (b) at Phi = 90° (c) at Theta = 0° (d) at Theta =9 0°

The Fig.8 shows the radiation patterns obtained from the simulation of the proposed antenna is E field is like the dipole radiation pattern and the H field azimuth pattern of radiation which follows the omnidirectional pattern which clearly shows that the proposed antenna has better radiational characteristics to support 3.8GHz Wi-Max wireless communication applications.

The Table.2 compares the performance of the proposed antenna with the existing methods.

Table.2. Comparison of proposed work with existing techniques

Reference	Overall Dimension (mm)	Resonant Frequency (GHz)	Gain (dB)	Patch Shape
[7]	100×100×1.6	3.5	8.9	Square
[8]	22×24×1.6	2.48 and 3.49	2.4 and 3.5	Square
[9]	38×25×1.6	2.4 - 6	1.2 - 2.85	Annular Ring
[10]	20×22×1.6	2.4 and 5.5	1.6 - 2.96	U Shaped slot
[11]	33×24	3.8 - 7	4	Trident Shaped
[12]	12×20×1.6	3.9 - 7.1	3.7	Audi Slot
[13]	35×35×1.6	3.58 - 4.40	5	Rectangular DRA
[14]	3.05×22.86 (cm)	5.1 - 5.8	4.5	Circular array
Proposed	20×16×1.6	3.8	1.78	Novel Fork Shaped

From the Table.2, it is seen that the proposed antenna achieves improved performance over a smallest dimension than the works cite in the references.

The Table.3 summarizes the overall results obtained by the proposed antenna.

Table.3. Overall Results

Parameter	Value
Frequency	3.8GHz
Return Loss	-26dB
VSWR	1.2
Gain	1.78dBi
Efficiency	92%
Bandwidth	400MHz

5. CONCLUSION AND FUTURE WORK

A novel patch antenna for 3.8GHz UAV Wi-MAX applications deliberated in this paper. The proposed antenna simulated in CST Microwave Studio V2019 and its results such as return loss of -26dB, VSWR of 1.2, gain of 1.78dBi and larger bandwidth of 400MHz are following the guidelines for operating Wi-MAX applications in ISM Band frequency. The proposed antenna has smaller dimensions when compared to the previous works listed in literature and its performance parameters were suitable for Wi-MAX applications. The future work will be focusing on improvement of its gain and other performance parameters.

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