A Monopole Antenna with U-Shaped Slots for Wireless Applications

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***Abstract* –** Antennas are alarmingly becoming a bridge between invisible Electromagnetic frequencies and visible electronic gadgets. It is a means to achieve communication in today's Era. Likewise, a monopole antenna is designed and fabricated in this paper, which operates in WLAN, WiMax and UWB frequencies. The antenna has two U-shaped slots embedded in the circular patch and feedline fed with coplanar waveguide. The modeling equations are elaborated with circuit analysis for the antenna. It has desirable gain features ranging from 3.56 dBi to 5.6 dBi with good radiation efficiency.

***Keywords*–**

Circular patch, U-shaped slots, coplanar feed, equivalent circuit, Modeling equations, impedance bandwidth, current distribution.

I. INTRODUCTION

IEEE 802.11 standards for WLAN consist of 2.4 GHz (2.4–2.484 GHz), 5.2 GHz (5.15–5.35 GHz), and 5.8 GHz (5.725–5.825 GHz) frequency bands and IEEE 802.16 standards for WiMaX consist of 2.5-2.69 GHz, 3.40-3.69 GHz and 5.25-5.85 GHz [2][9]. Also, there is an increasing demand for Ultra wide band applications which covers 3.1 to 10.6 GHz. In order to achieve all these frequency bands in one device, the following antenna is designed with monopole characteristics. Recently, printed monopole antennas have become prominent for WLAN and WiMAX applications due to its low cost, process simplicity, good performance and portability nature[5]. This paper provides detailed antenna dimensions and modeling of it in HFSS software. The circuital analysis is elaborated with equations governing it.

In[1], a monopole antenna with two curved stripes connected to feed point was proposed for WLAN USB dongle application which did not cover UWB range. A miniature triple band monopole was designed in [2] but the gains achieved were less than required. Many other designs of triple band antennas are either complex in structure with protruding parts or large in size, which limit their availabilities for practical applications. In paper[4], a mechanical conical monopole antenna was designed operable in X band and Ku band. But it hardly makes the device portable for ready use in the communication field where space is an essential criteria. Hence, there is a need for small portable antenna which can be easily installed in the mobile phones or network cards.

In this design, the monopole antenna covers WLAN, WiMax and some UWB ranges with acceptable gains and wide impedance bandwidth. The slots are designed to operate at particular resonating frequencies. It has relatively low VSWR and efficient radiation efficiency.

II. ANTENNA DESIGN AND APPLICATION BANDS

The prototype structure of the antenna designed here consists of a dual U-shaped slots embedded in the circular patch and feedline fed through a coplanar waveguide (CPW) transmission line, which is in turn connected to a coaxial cable through a standard 50Ω SMA connector. The antenna is designed on a low-cost, durable FR4 substrate having relative dielectric constant ε_r=4.4, loss tangent tanδ=0.02 and thickness of h=1.6 mm. The overall size of the antenna is 48x65mm^2; while the circular patch is of optimized radius of 12 mm. A 50 ohm CPW transmission line of a signal strip width of 3.8mm with a gap distance of 0.3mm between the strip and the coplanar ground plane is used for feeding the antenna. The Coplanar feed is considered in order to reduce surface waves[2]. The feedline of coplanar feed acts as signal conductor while the ground planes situated at either side on the feedline acts as returning planes.

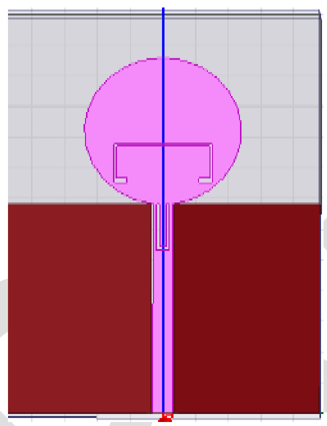

Fig.1. Design of monopole antenna with one U-shaped slot at the circular patch and other in the feedline.

The antenna is devised for the application in various WLAN (from 2.4-2.484 GHz, 5.15-5.35 GHz), WiMax (from 2.5-2.69 GHz, 3.3-3.8 GHz) and UWB (from 3.36-11.67 GHz) bands.

Table I

Parameter	**Unit (mm)**
Length of patch U-slot	32
Thickness of the slot	0.7
Length of the feedline U-slot	17.3
Radius of the circular patch	12
Ground plane dimension	34x22.2
Substrate dimension	48x65
Signal strip width	3.8

Table.1. Dimensions of the proposed antenna

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III. DESIGN METHODOLOGY AND PARAMETER ANALYSIS

In order to interpret the principle of the slot technique, the antenna is analyzed with equivalent circuit model. Fig.2. gives the equivalent circuit of the antenna in Fig.1. Zslot1, Zslot2 and Zant expresses the equivalent impedance of the inverted U-shaped slotline at the circular patch, the U-shaped slotline at the feedline and the circular patch respectively. It is supposed that the resonant frequencies of the patch and feedline slotline are, respectively, f1 and f2. It can be concluded that the circuit is shorted when f=f1 or f2, since the two pieces of shorted slotlines are of the lengths of $\lambda_1/2$ and $\lambda_2/2$, respectively.

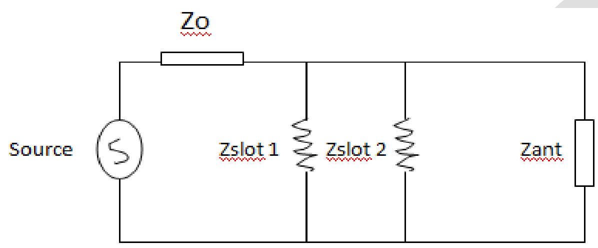

Fig.2. Equivalent circuit model of the antenna with two U-shaped slots expressed in the impedance form.

The Zo represents the characteristic impedance of the equivalent circuit. For resonating frequency, f_1=4.05 Ghz, the length of the slot of the patch is $Lslot_1$=32 mm and for resonating frequency, f_2=7.5 Ghz, the length of the slot of the feedline is $Lslot_2$=17.3 mm. The slot lengths are evaluated using the following formula;

$L_{slot=}C/[2f_o\{\sqrt{(_r+1)}\}/2]$.

The effective permittivity, ε_e is slightly less than εr because the fringing fields around periphery of the patch are not confined in the dielectric substrate but spread in the air. For FR-4 substrate, ε_r=4.4 and h=1.6mm;

$\varepsilon_{e=}\{\sqrt{(\varepsilon_r+1)/2}\}+\{\sqrt{(\varepsilon_r-1)/(2\sqrt{(1+(10h/W))})}\}$; therefore, ε_e =4.017.

The width of the patch is evaluated by the formula, W= $C/[2f_o\{\sqrt{(\varepsilon_r+1)}\}/2]$.

For f= 3.8 Ghz; W= 24mm (Diameter of the circular patch). The other parameter, effective length is evaluated in the antenna to understand the actual length extension of the antenna. The effective length is increased due to fringing effect. It is calculated as;

$L_e=L+2\delta L= C/\{2 f_o\sqrt{(\varepsilon_e}\}$; for resonating frequency, f =4.5 Ghz , therefore Le=75 mm.

IV. RESULTS AND DISCUSSION

The antenna is designed and simulated with the help of HFSS – a high performance full wave EM field simulator. The results are optimized in HFSS and the frequency of operation , antenna gain and other antenna parameters are obtained. Fig.3 describes the simulated return loss against the frequency for the prototype antenna.

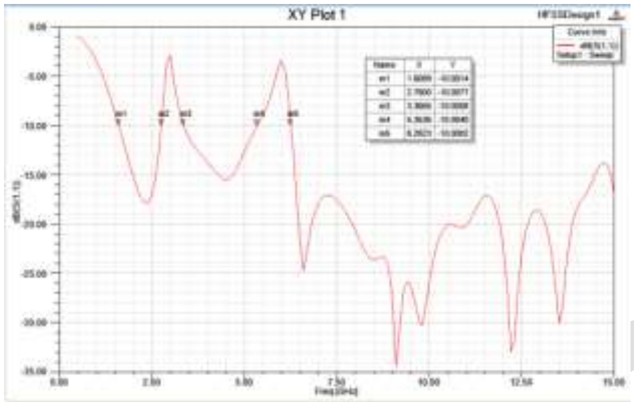

Fig.3 Reflection coefficient plot showing good impedance bandwidth of 1160 MHz at 1.6 to 2.76 Ghz and 1987 MHz at 3.366 to 5.353 Ghz.

U-shaped slot needs to be etched efficiently in order to obtain proper operating frequency. The result shows wide bandwidth response. The lower band of the proposed antenna has an impedance bandwidth of 1160 MHz (1.6-2.76 Ghz) and higher band has BW of 1987 MHz (3.366-5.353 Ghz) covering WLAN, WiMax and UWB bands.

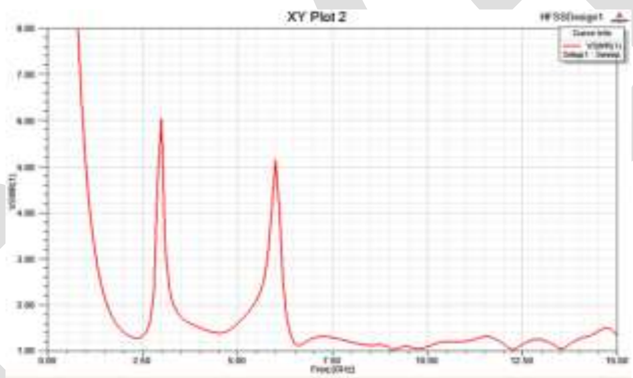

Fig.4. VSWR plot showing voltage standing wave ratio less than 2dB (Ideally VSWR<=1).

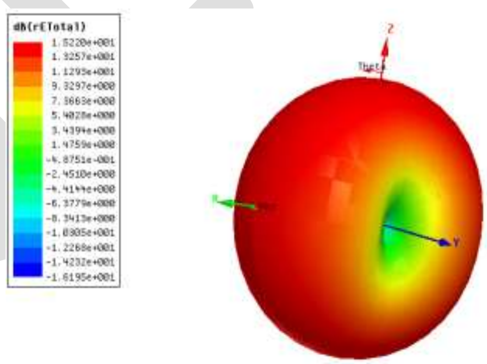

Fig.5. 3-D radiation plot for designed monopole antenna showing good omnidirectional radiation.

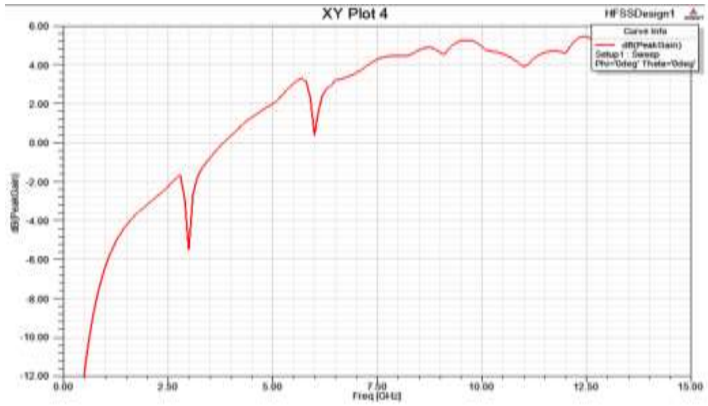

Fig.6 Peak Gain curve showing maximum gain at 9.2 GHz, whereas gain at WLAN band is about 2.05 dBi and at WiMax it is near to 1.06 dBi.

The gain increases with frequency and is maximum at 9.2 Ghz. Achievable gain at WLAN band is about 2.05 dBi and at WiMax its 1.06 dBi. The proposed antenna has a larger gain in the higher bands because the antenna gain is a function of its electrical dimensions relative to the wavelength of interest, current/field distribution and radiation pattern[13].

V. CONCLUSION

Good antenna radiation performance of operating frequencies across the WLAN, WiMaX & UWB bands are obtained. By embedding two U- shaped slots, efficient impedance bandwidth is achieved with gain ranging from 1.06 dBi to 5.32 dBi. Also, proper E-plane radiation is observed at desired frequencies giving the omnidirectional radiation nature for the monopole antenna.

VI. FUTURE SCOPE

It can be further modified for achieving higher frequencies by increasing slot structures. Also, necessary filter notch can be inserted in the design in order to eliminate unnecessary frequency.

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