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C-SLOT TRIANGULAR SHAPE MONOPOLE MICROSTRIP PATCH ANTENNA FOR HIGH FREQUENCY (K AND KA BAND) APPLICATIONS

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Abstract- In this paper, a wideband microstrip patch antenna for K and partial Ka band applications are proposed. The proposed antenna structure consists of C-slot triangular patch with etched edges. The edges are cut for obtaining wide bandwidth. Simulation of proposed antenna is done through Ansoft's high frequency structure simulator (HFSS version 14.0). The prototype is taken with size (20 x 20 x 1.6) mm that attains constant group delay, wide bandwidth and good radiation patterns for the whole operating bandwidth from 15 GHz to 36 GHz (21 GHz) with 82.35% impedance bandwidth at 25.5 GHz centre frequency. The measured result of proposed antenna shows fine conformity with the simulated result. Hence, the proposed antenna is applicable for wireless and satellite communication in UWB (ultra wide band) range for K and partial Ka bands.

***Index Terms*- K band, Partial ka band, UWB, Microstrip Antenna.**

I. INTRODUCTION

In modern era, speedy changes in wireless communication system lead to a need of an antenna that can nurture services like Wireless Local Area Network (WLAN), UWB (Ultra Wide Band) and Bluetooth. Multipurpose ultra wide band antenna has become popular after their adoption by Federal Communication Commission (FCC) in 2002 [1], [2]. UWB antennas are capable of replacing various integrated antenna elements on the IC's of handheld devices there upon making equipments versatile and portable. Manufacturing of UWB antennas [3], [4] offered low cost with high data rate, low consumption of power, short range of operation and simplest design features [5]. Properties like light weight, low profile, conformal design, ease of integration and fabrication [6] has increased the popularity of UWB microstrip patch antenna.

Present day studies on patch antenna is notably shifting to higher frequency band (Kurtz-under (Ku), Kurtz (K) and Kurtz-above (Ka) bands) due to plentiful applications in the field of mobile, radar, communication or broadcast satellite services [7]-[10].

According to the norms of international telecommunication union, researchers are resurging in researches on designing or optimizing antennas for direct broadcast services (DBS) [11], [12] and fixed satellite services (FSS) [13]-[16].

A monopole C-slot triangular patch antenna operating in K and partial Ka band is proposed in this article. This new design operates for Kurtz band and partially for kurtz-above band (15 - 36 GHz).

Ansoft HFSS (version 14.0) tool has been used for designing and simulating the proposed patch antenna. This paper is structured into five different sections. The configuration and specification of proposed UWB antenna are shown in "section II". The results of antenna parameters are explored in "section III". The measured and simulated results for various parameters of proposed antenna are discussed in "section IV" and a brief conclusion is presented in "section V".

II. ANTENNA CONFIGURATION

The proposed geometric structure of C-slot triangular shape monopole microstrip patch antenna is exhibited in Fig. 1(a,b).

The proposed patch antenna is printed on a 1.6mm thick FR4 substrate having length and width 20x20 mm^2 respectively.

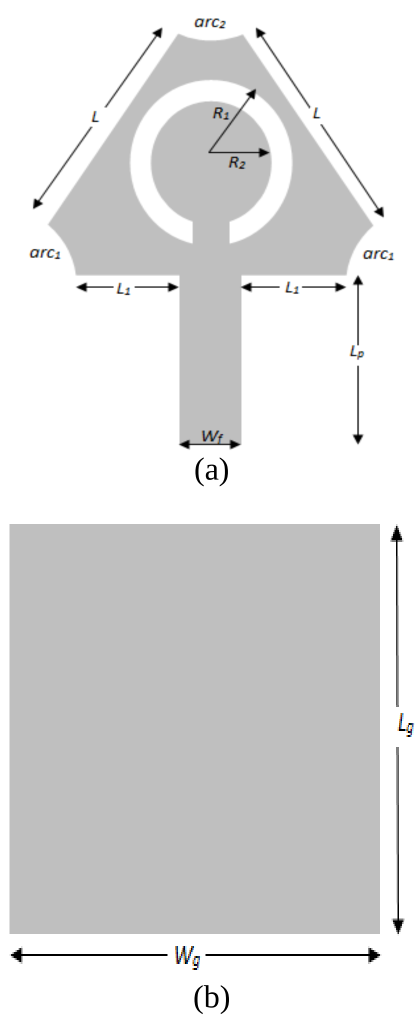


Fig.1. (a) Radiating patch (top View), (b) Ground (bottom View) of proposed c-slot triangular shape monopole microstrip patch antenna.

In proposed antenna, the excitation is provided by microstrip feed line connector of 50 Ω characteristic impedance. The ground of the proposed antenna is square in shape, while the initial shape of radiating patch is equilateral triangle. In order to enhance impedance bandwidth, a C-shape slot is cut in triangular shape radiating patch.

Further modification in the proposed antenna is done to enhance its bandwidth by etching the arc on each edge of triangular patch. The arc radius is calculated with the help of equation 1-

$$arc = \frac{\theta}{360}\ x\ 2\pi r \qquad (1)$$

The width 'W' and length 'L' of the patch of antenna prototype can be calculated by following equations-

$$W = \frac{(2M+1)}{\sqrt{\frac{\epsilon_r+1}{2}}}\ \text{x}\ (\lambda o/2) \qquad (2)$$

$$L = \frac{(2N+1)}{\sqrt{\epsilon_{eff}}}\ \text{x}\ \left(\frac{\lambda o}{2}\right) - 2\ \text{x}\ \Delta L \qquad (3)$$

where, M & N are positive integers, ϵ_{eff} & ϵ_r are effective and relative permittivity respectively, ΔL is patch length expansion due to fringing effect and it is given by-

$$\frac{\Delta L}{h} = 0.412\ [\frac{\epsilon_{eff} + 0.3}{\epsilon_{eff} - 0.258}][\frac{W/_h + 0.264}{W/_h + 0.813}] \quad (4)$$

The effective patch length L_e can be given as-

$$L_e = l + 2\Delta L \qquad (5)$$

(a)

(b)

Fig.2. Proposed fabricated c-slot triangular shape monopole microstrip patch antenna (a) Top-View, (b) Bottom-View.

Table 1- Various variables of the proposed c-slot triangular shape monopole microstrip patch antenna.

Variables	Units (mm)
L_g	20
W_g	20
W_f	2
L	9
L_1	3
L_p	3
R_1	4
R_2	3.15
arc_1	4
arc_2	3

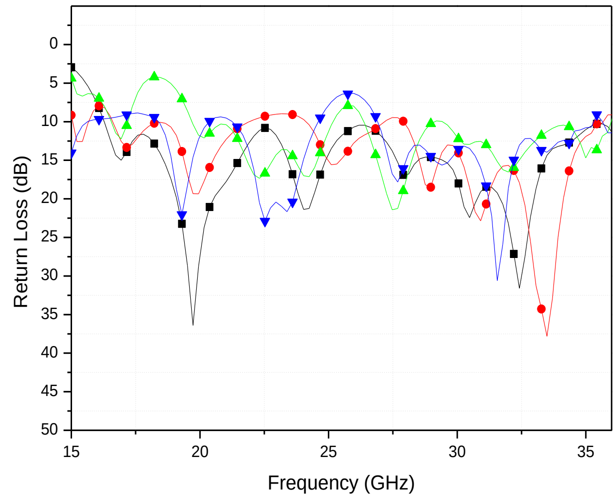


Fig.3. Simulated return loss versus frequency for (i) triangular antenna, (ii) c-section slot antenna, (iii) antenna with single arc, (iv) proposed antenna with ground plane remains same for all the various shapes of patch.

Ansoft HFSS (High frequency structure simulator) version 14.0 based on finite element method 3-D electromagnetic solver is used for modelling and optimizing the proposed antenna results.

Fig. 3 depicts the proposed antenna radiator evolution along with its correlative return loss curves. Firstly, an equilateral triangular shape radiating patch (trace (i)) is formed. The simulated return loss curve indicates that the radiator resonates for narrow band regions 5.2 GHz and 8.6 GHz. In the second step, C-shape slot is etched in the radiating patch for which return loss curve is presented by trace (ii) that fails to resonate for wide band region. By cutting the upper edge of triangle third radiating patch is formed, whose return loss curve is shown by trace (iii), that again fails to resonate for entire UWB region. Finally, the other two edges of triangle are also etched that provides the final effective radiating patch, for which the return loss curve is illustrated by trace (iv) and covers the entire operating band from 15 to 36 GHz with resonating frequencies 19.72 GHz, 24.03 GHz and 32.41 GHz.

III. PARAMETRIC STUDY OF THE PROPOSED C-SLOT TRIANGULAR SHAPE MONOPOLE MICROSTRIP PATCH ANTENNA

In this region, the influence of the various design values on antenna performance is considered and discussed. At a time, the variation in one value is considered while others are kept constant for analyzing the better performance of the proposed antenna. The outcome of these parametric changes provides strategic help in improvising the final design of antenna before fabrication. Therefore, effect of varying inner radius of C-section slot (R_2) and microstrip feed width (W_f) are taken into consideration.

Fig. 4 shows the simulated results of the C-slot triangular shape monopole microstrip patch antenna with different values of outer radius (R2). It is keenly observed that by varying the values from 3.30 mm to 3.05 mm the proposed antenna does not covers the entire frequency range. However, the value R_2 = 3.15 mm covers full operating band with improved impedance matching condition and better return loss. Therefore, R_2 = 3.15 mm is taken as the optimum value for the proposed antenna that covers the entire bandwidth from 15 to 36 GHz.

The simulated results of the C-slot triangular shape monopole microstrip patch antenna, with microstrip feed width (W_f), varying from 1.5 to 2.5mm are depicted in fig. 5.

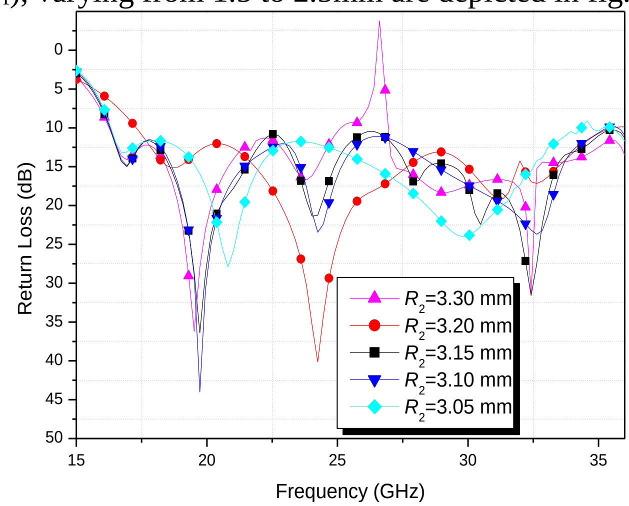


Fig.4. Simulated return loss(dB) with respect to frequency (GHz) for various values of C-section slot width; while leaving all other parameter same as mentioned in table 1.

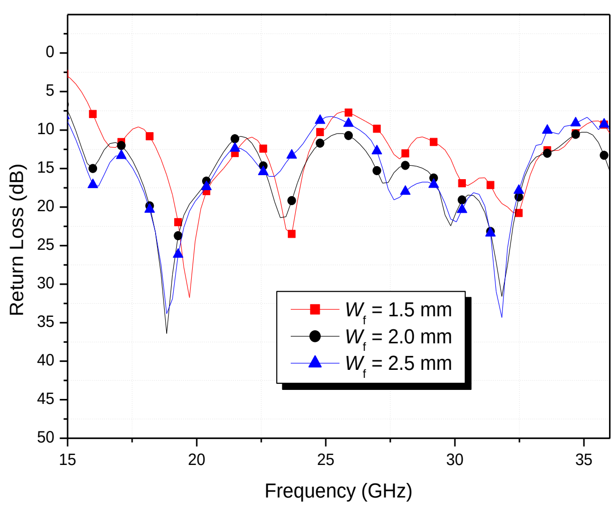


Fig.5. Simulated return loss in (dB) with respect to frequency(GHz)for various W_f (feed width); other parameters will remain the same as shown in table 1.

It can be observed that the proposed antenna does not enfold the entire operating band for W_f = 1.5mm. Although for W_f = 2.0mm the return loss condition improves, as it covers the entire operating band. Further enhancement in the value of feed width shows the deterioration of frequency band. Therefore, it is decided to take W_f = 2.0mm as the optimum value of feed width with good impedance matching of the radiating patch.

The outcome obtained by different parameters variation shows that the proposed antenna gives better impedance bandwidth performance under optimized dimensions realized for the antenna.

IV. DISCUSSION OF EXPERIMENTAL & SIMULATED RESULTS

The proposed antenna performance such as return loss, group delay, gain and radiation pattern are discussed here. The proposed antenna is etched on PCB (Printed Circuit Board) board which are mostly made by FR4 having ϵ_r (relative permittivity) = 4.4. PCB etching is a established reliable process for antenna construction. The design of proposed antenna was formed on copper sheet by using etching process. Etching process was done by using milling machine (MITS, Eleven Lab).

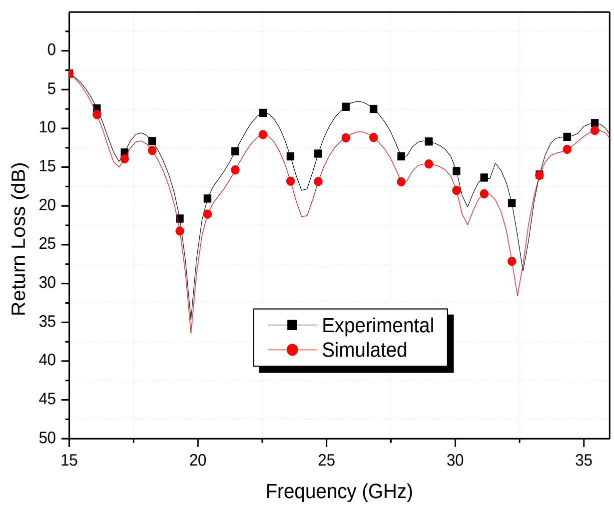


Fig.6. Simulated and experimental return loss versus frequency for the proposed c-slot triangular shape monopole microstrip patch antenna.

Fig. 6 presents the comparison curve between experimental and simulated return loss of C-slot triangular shape monopole microstrip patch antenna which are in good compliance. The variation between experimental and simulated graphs is due to the combined effect of RF cable, SMA (sub-miniature version A) connector soldering, fabrication tolerance and dielectric constant variation at high frequency.

The group delay of the C-slot triangular shape monopole microstrip patch antenna is shown in fig.7. Group delay plays an important role for designing the wideband antenna.

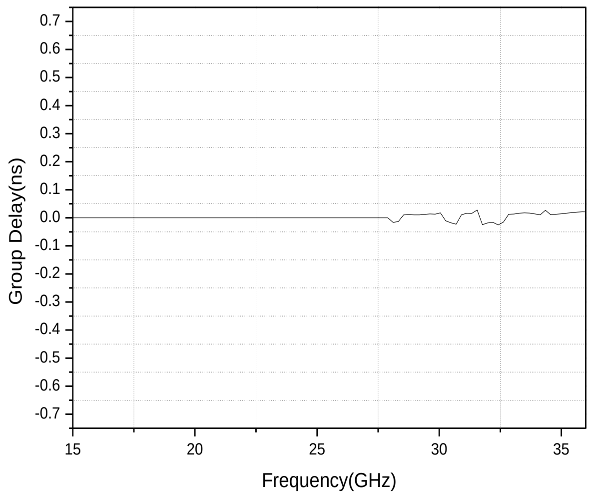


Fig.7. Simulated group delay in contrast with frequency(GHz) for proposed antenna.

Group delay shows the effective transmission of waves in the wireless communication. It is noticed that the group delay for the proposed antenna is less than 1ns for entire frequency range 15 to 36 GHz, that is required for distortion less transmission in UWB antenna.

Gain is one of the significant parameter in designing of microstrip patch antenna. Fig 8 depicts the simulated and experimental gain of the proposed antenna. The gain of the proposed antenna varies within 1.1-4.67/ 1.7-5.2 dBi over the entire operating band ranges from 15 to 36 GHz. The simulated and experimental results of gain are in good agreement of each other.

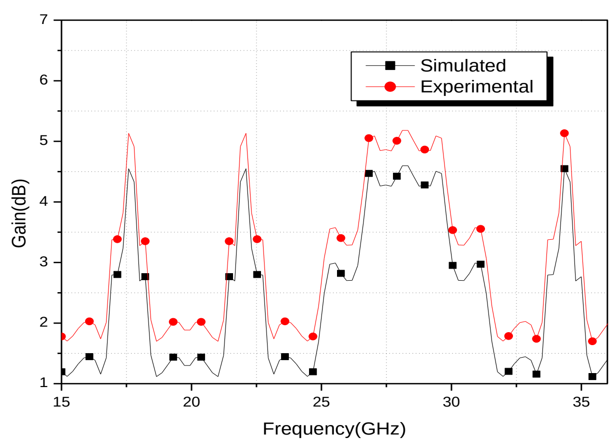
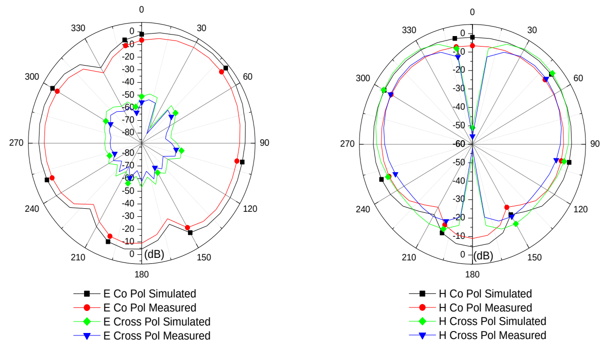
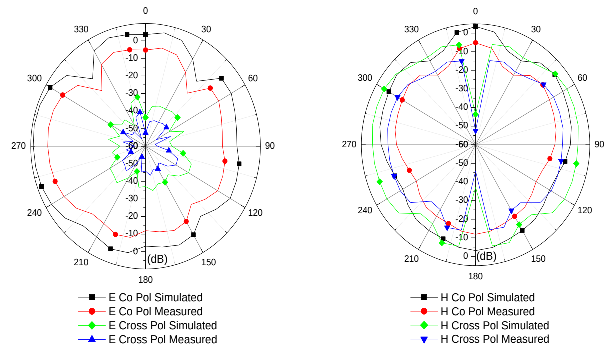


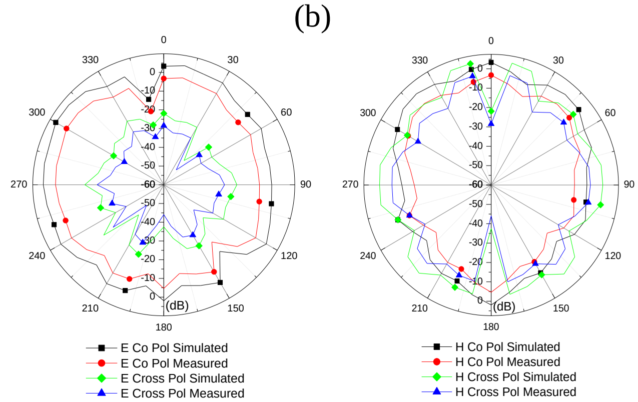
Fig.8. Simulated & Experimental gain (dB) for the proposed monopole C-slot angular patch antenna.



(a)



(b)



(c)

Fig.9. Measured and Simulated radiation patterns at different frequencies for C-slot angular patch proposed antenna: (a) 19.72 GHz, (b) 24.03 GHz, and (c) 32.41 GHz.

Fig. 9(a)-(c) shows acceptable radiation pattern characteristics for proposed C-slot triangular patch antenna. The radiation pattern is obtained at frequencies 19.72 GHz, 24.03 GHz, and 32.41 GHz respectively for E and H planes. Measured and simulated results of radiation pattern show good agreement.

Table 2 demonstrates a comparative depiction between the proposed antenna and some other existing antennas related in terms of size, operating frequency band, gain and operational applications. From this comparative table it is found out that the proposed patch antenna illustrate enhanced results in K and partial Ka band with respect to other antennas.

Table 2-Comparative depiction of proposed antenna with other antennas

Ref	Area of antenna (mm^2)	Operating Frequency Band (GHz)	Gain (dB)	Relative Dielectric Constant (ϵ_r)	Applications
[17]	40x35	12–16.4 / 17.53–19.5	4.68 /3.17	10.2	Ku/k band
[18]	20x20	11.97-20.54	8.5	4.4	Ku/K band
[19]	30x15	16.60-18.72 / 22.66-23.43	6.02 / 3.62	4.4	Ku/k band
[20]	17.1x28.1	4-40	2.8	4.4	Ku/k band
Proposed	20x20	15-36	4.67	4.4	k/ka band

V. CONCLUSION

A microstrip fed triangular C-slot antenna is proposed for K and partial Ka band applications. The antenna size is compact enough to be mount on satellites. This antenna attains acceptable return loss, sustained group delay, satisfactory gain and better radiation pattern characteristics for whole operating bandwidth ranges from 15 GHz to 36 GHz (21 GHz) having 82.35% fractional bandwidth. The proposed antenna has maximum gain of about 4.67dB/ 5.26dB. The outcomes (simulated and measured) of the proposed antenna depicts a satisfactory conformance, that makes the presented antenna suitable for K/partial-Ka band applications.

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