CPW-fed Elliptical Slot UWB Antenna with a Tuning Uneven U-shape Stub on Liquid Crystal Polymer (LCP)

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Abstract: The implementation of a compact CPW-fed elliptical slot antenna with an uneven U-shape tuning stub that demonstrates good impedance match, omni-directional radiation patterns and relatively high gain in the whole ultra wide band range (UWB) is discussed in this paper. The proposed antenna is fabricated on 350 μm thick liquid crystal polymer (LCP) with an overall board dimension of 32 mm x 40 mm. It is fed by a CPW line and the inner conductor becomes an uneven U stub for improved matching that radiates inside an elliptical slot. The uniplanar compact antenna demonstrates simulated and measured return loss below -10 dB in the UWB range of frequencies. The simulated and measured radiation patterns present omni-directional behavior in both E and H planes while the average measured gain varies between 3.8 dBi and 6.1 dBi.

Keywords: Compact antenna, Elliptical slot antenna, LCP, U-shape tuning stub, UWB

1. Introduction

The Ultra Wide Band protocol was released from FCC in 2002 [1] covering the frequency range from 3.1-10.6 GHz, partly as an attempt to meet the demand for high data rate communications in short distances for mobile and personal applications. Therefore, there is a need for compact sized, low cost and high efficiency antennas with omni-directional radiation patterns. The combination of these characteristics in a wide frequency range such as the UWB band is a challenging problem and several design concepts and different materials have been used in an attempt to provide a satisfactory solution. Many researchers have proposed a fat monopole approach [2-3]. A different approach is the use of microstrip fed slot [4] or CPW fed [5] slot antennas. These slot antennas though are significantly larger than the monopole competitors. The endfire antenna on LCP proposed in [6] is also large, being multiple wavelengths long.

In this paper a novel, compact, CPW-fed elliptical slot antenna with an uneven U-shape tuning stub on LCP is proposed. To widen the impedance matching bandwidth, a linear tapered CPW line and an uneven U-shape stub are used. Return loss and radiation patterns are presented and discussed. The fabricated prototype demonstrates good matching and omni-directional patterns with relatively high gain throughout the whole UWB frequency range.

2. Antenna Design and Fabrication

The fabricated slot antenna is presented in Fig. 1. It is fabricated on a 350 μm thick, low loss ($\tan\delta$=0.002), low dielectric constant (ε_r=3), Liquid Crystal Polymer (LCP) with a copper layer that is 18 μm thick. The LCP material is conformal with an engineered CTE [7]. Standard photolithography was used for the fabrication.

The schematic of the proposed antenna is presented in Fig. 2 and the dimensions are summarized in Table 1. Ansoft HFSS software [8] was used to design the proposed structure and optimize the radiation pattern and return loss. The stub dimensions and the linear tapering effect the matching while the ellipse size has some effect on the radiation patterns. The proposed antenna is fed by a CPW line with an inner conductor width, W, of 2.2 mm and a gap, g, between the ground and the inner conductor of 0.3 mm. At a distance S=9.9 mm from the board edge, the inner conductor is linearly tapered until its width becomes 0.9 mm to improve the matching between the transmission line and the U-shape stub. The U-shaped stub consists of a semi annular ring and two linear segments. The semi annular has an outer radius R=5.5 mm and inner radius r=3.5 mm. The left linear segment has length S1=5 mm and width d=3 mm while the right linear segment has length 6 mm and width d=3mm. The center C of the semi annular ring is 4.1 mm from the ellipse center O and the ellipse center is 22 mm from the bottom edge. The ellipse has a major axis equal to L1=30 mm and secondary axis equal to L2=20 mm. The overall board dimensions are 40 mm x 38 mm.

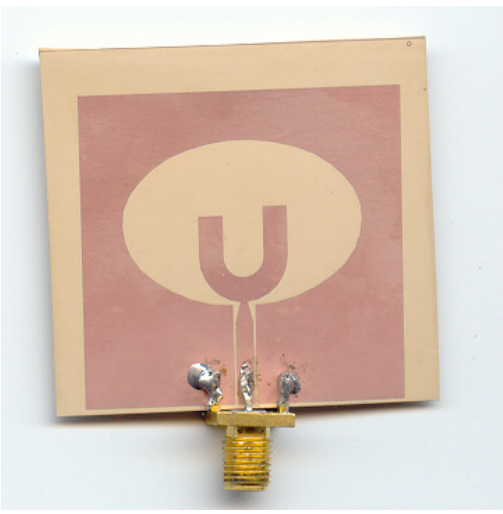

Fig. 1. Fabricated Antenna

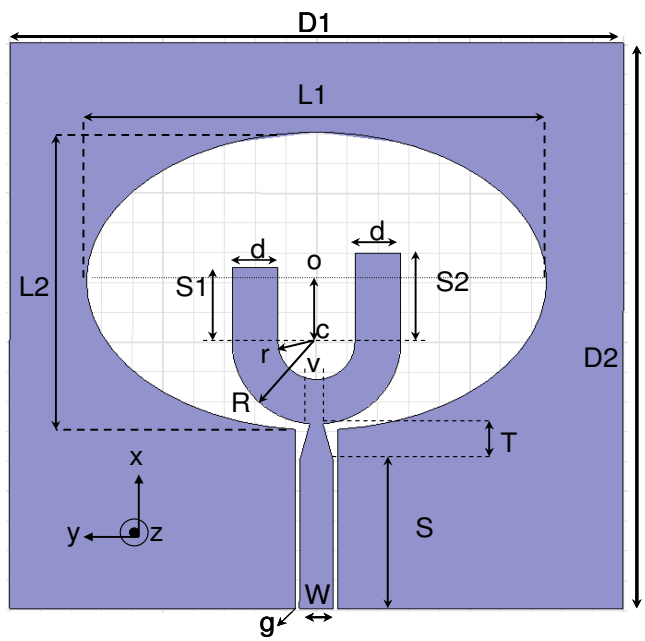

Fig. 2. Antenna Schematic

Table 1. Antenna Dimensions

D1	40 mm	r	2.5 mm
D2	38 mm	R	5.5 mm
W	2.2 mm	S1	5 mm
g	0.3 mm	S2	6 mm
v	0.9 mm	d	3 mm
S	9.9 mm	L1	30 mm
T	2.5 mm	L2	20 mm
OC	4.1 mm		

3. Discussion of Measurements and Simulation Results

For return loss and radiation pattern measurements, an SMA connector is soldered onto the board. An HP8530 Network Analyzer was used to measure the return loss, which is shown in Fig. 3 with the simulated return loss. Two main resonances are observed in both the simulated and measured return loss plots which are controlled by the two linear segments on the U-shape stub. The simulated return loss is well matched from 3 GHz to over 12 GHz, but the measured return loss is greater than -10 dB only, however it remains matched up to the frequency of through10.6 GHz, which is the upper bound for UWB frequency range.

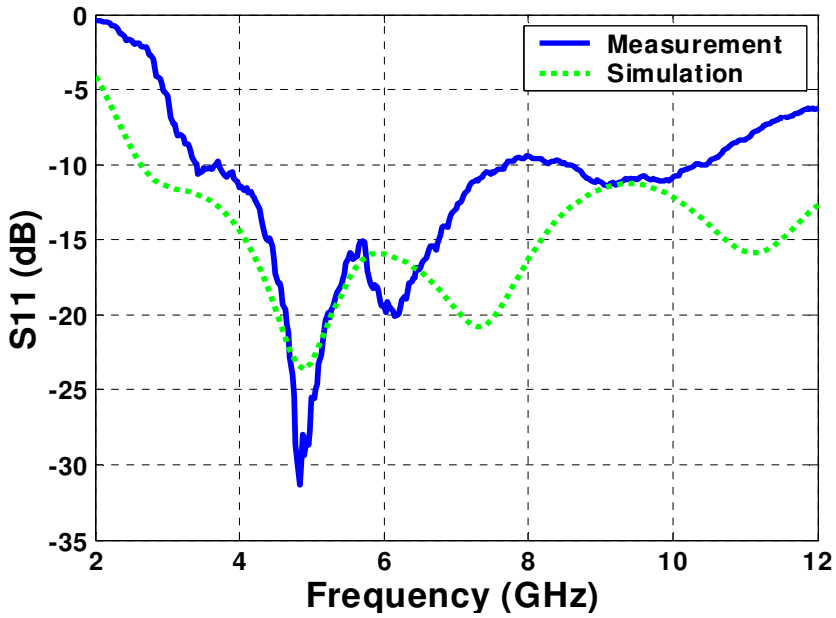

Fig. 3. Return Loss measurement and simulation

The measured radiation patterns are omni-directional in the H plane and they present a null in the E plane and the plane parallel to the slot (x-y). All the measurements involve the phi polarization of E field. Only measurements in two frequencies are presented, at 4 GHz and at 8 GHz, however the radiation patterns present similar behavior in the whole UWB range. In Fig. 4 the patterns in x-y plane are presented. The phi=0 corresponds to the x axis. Fig 5 presents the plots in E plane (x-z), where theta=0 corresponds to z axis and theta=90 corresponds to the x-axis. The H plane (y-z) plots are presented in Fig. 6 where theta=0 is the z- axis and theta=90 is the y-axis. The null in x-axis direction is because of the feed line while in H plane the patterns are omni-directional. The measurements span only 180 degrees but in the measured range are in very good agreement with the simulated results. The proposed slot antenna has relatively high gain. The maximum gain was measured at 5 dBi at 4 GHz and 4 dBi at 8 GHz. The lower gain at 8 GHz is because the relatively poorer matching at this frequency.

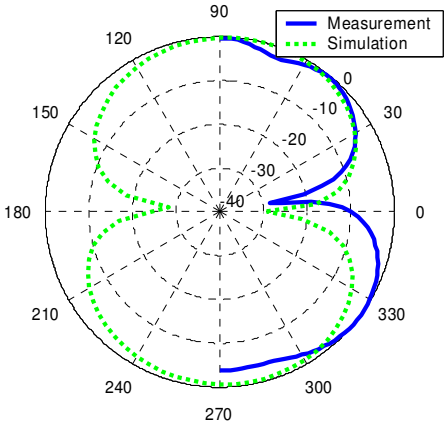

Fig 4a. x-y plane f=4 GHz

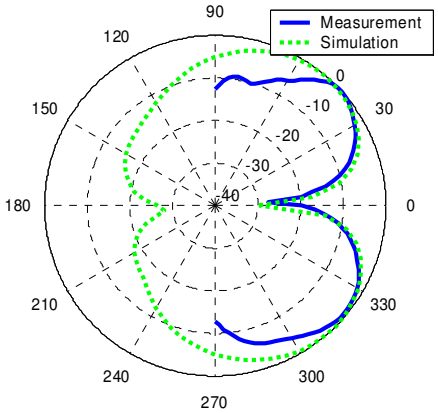

Fig 4b. x-y plane f=8 GHz

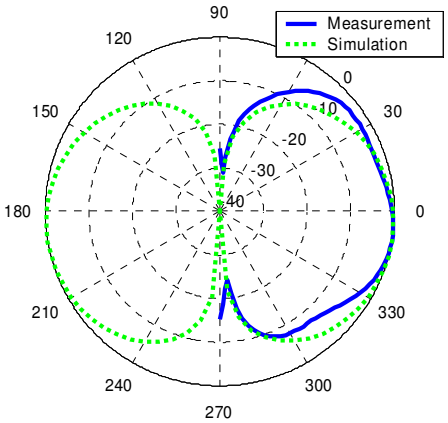

Fig 5a. E plane f=4 GHz

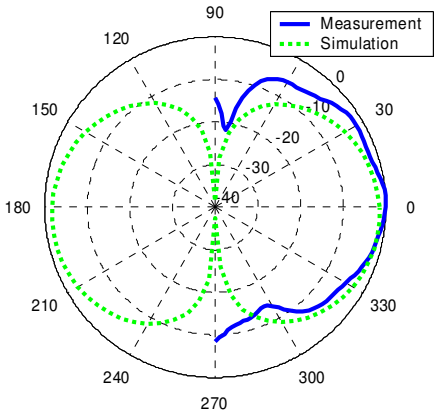

Fig 5b. E plane f=8 GHz

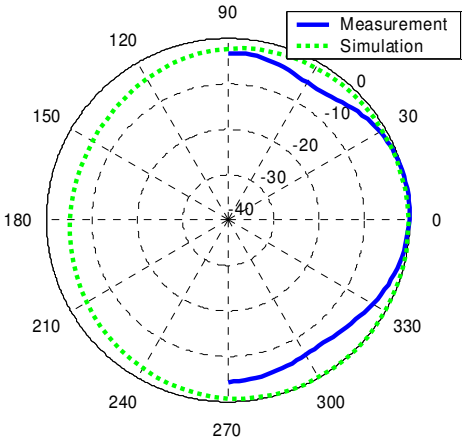

Fig 6a. H plane f=4 GHz

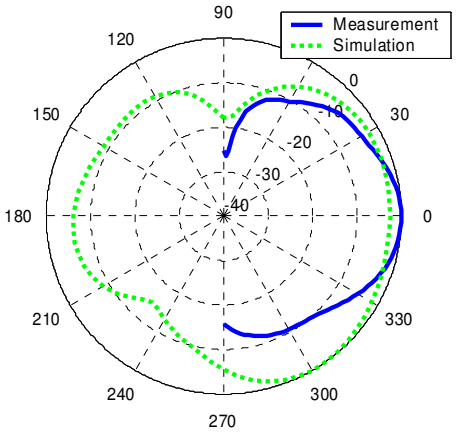

Fig 6b. H plane f=8 GHz

4. Conclusions

The proposed antenna is fabricated on flexible, low loss and low cost LCP material. The presented slot antenna has return loss better than -10 dB in the whole UWB range and has omni-directional radiation patterns. It exhibits relatively high gain and the measured radiation patterns maintain the omni-directional characteristic in all frequencies in the UWB range. The aforementioned characteristics make the CPW-fed elliptical slot antenna with an uneven U-shape tuning stub a very good candidate for mobile personal communication devices.

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