CPW-fed Ultra Wideband (UWB) Monopoles with Band Rejection Characteristic on Ultra Thin Organic Substrate

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Abstract — **Two CPW-fed compact elliptical monopole UWB antennas are introduced with band rejection characteristic at the band used for wireless LAN applications. The antennas are fabricated on ultra thin (100 µm) liquid crystal polymer (LCP) and the band notch is caused by the presence of a resonating slot within the elliptical radiator. The two investigated antennas have a U-shaped slot and a C-shaped slot respectively. From the presented return loss and VSWR measurements, the C-shaped slot causes a wider rejection band compared to the U-shaped slot that could be used for the design of UWB antennas with reconfigurable sub bands. Both designs present almost identical radiation pattern behavior with the design without any slot with the exemption of the gain in the frequency notch band, which is maintained negative.**

Index Terms — **Antenna, Band rejection, Liquid crystal polymer, Ultra wideband.**

I. Introduction

FCC released the Ultra Wide Band protocol that covers the frequency range from 3.1-10.6 GHz in 2002 [1], as an attempt to meet the demand for high data rate communications in short distances for mobile and personal applications. However the designated band overlaps with the HIPERLAN/2 bands (5.15-5.35 GHz, 5.470-5.725 GHz) and the IEEE 802.11a bands (5.15-535 GHz, 5.725-5.825 GHz) which can interfere with the UWB communication systems. Therefore there is a need for UWB antennas with band rejection characteristics in the aforementioned frequency bands. Several ideas have been introduced by different researchers in order to design compact antennas with the desired features. The use of parasitic patches has been used in [2], a tuning stub has been used in [3] while short stubs on a slot line have been proposed in [4]. Nevertheless the most popular solution has been the introduction of a U-shaped slot in a microstrip fed monopole which has been used by many researchers [5-7]. In those cases the used substrates were relatively thick varying between 0.762 mm in [5] to 1.6 mm in [7].

In this paper two CPW-fed elliptical monopoles fabricated on ultra thin (100 µm) LCP (liquid crystal polymer) material with band-notch characteristics are introduced. The two fabricated prototypes which use a U-shaped slot and a C-shaped (circular arc) slot respectively are analyzed and compared. The slot presence causes the frequency notch while it doesn't affect the radiation pattern behavior which remains consistently omni-directional.

Fig. 1. Fabricated prototypes.

II. Antenna Design and Fabrication

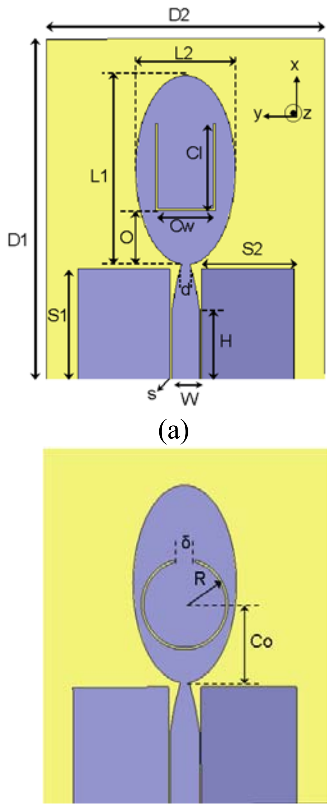
A. Fabrication

The proposed antennas are presented in Fig. 1. They are fabricated on low loss (tanδ=0.002), low dielectric constant (ε_r=3), LCP with a copper layer that is 18 µm thick. The CPW-fed elliptical monopoles are fabricated on a very thin, 100 µm thick substrate. The LCP material is conformal with an engineered CTE [8]. Standard photolithography was used for the fabrication.

B. Schematic Discussion

The schematics of the fabricated antennas are presented in Fig. 2 and the dimensions are summarized in Table I. Ansoft HFSS software [9] was used to design the presented prototypes and for the radiation pattern and the return loss optimization.

The proposed antennas are fed by a CPW line with an inner conductor width, W, of 2.75 mm and a gap, s, between the ground and the inner conductor of 0.18 mm. At a distance H=6.38 mm from the board edge, the inner conductor is linearly tapered until its width becomes 0.84 mm to improve the matching between the transmission line and the elliptical radiator. The elliptical monopole has axes



(b)

Fig. 2. Elliptical monopole schematic with (a) U-shaped slot (b) C-Shaped slot

L1 equal to 17.60 mm and L2 equal to 9.68 mm. For compact UWB antennas the design and optimization of the ground size is critical for the overall antenna performance. The ground patches used for this structure have dimensions 10.38 mm by 8.94 mm that result in a very compact design. The frequency notch resulted in the return loss measurements, is due the slot on the elliptical monopole. The U-shaped slot is placed at a distance O, 4.97 mm from the end of the feed line and is consisted by two parallel segments 8.1 mm long and a third segment perpendicular to the feed line direction which is 5.40 mm long. The total length of the U-shaped slot is 21.85 mm and the slot width is 0.2 mm. The C-shaped slot on the second prototype is a circular arc of 3.85 mm radius. The center of the arc is placed at a distance Co, 6.97 mm far from the end of the feed line and the chord δ is 2 mm long. The C-shaped slot has total length 23.44 mm and is also 0.2 mm wide.

Other than the slot's shapes and positions the presented prototypes are identical and they are fabricated on a 100 μm thick LCP board with dimensions 32 mm by 26.80 mm

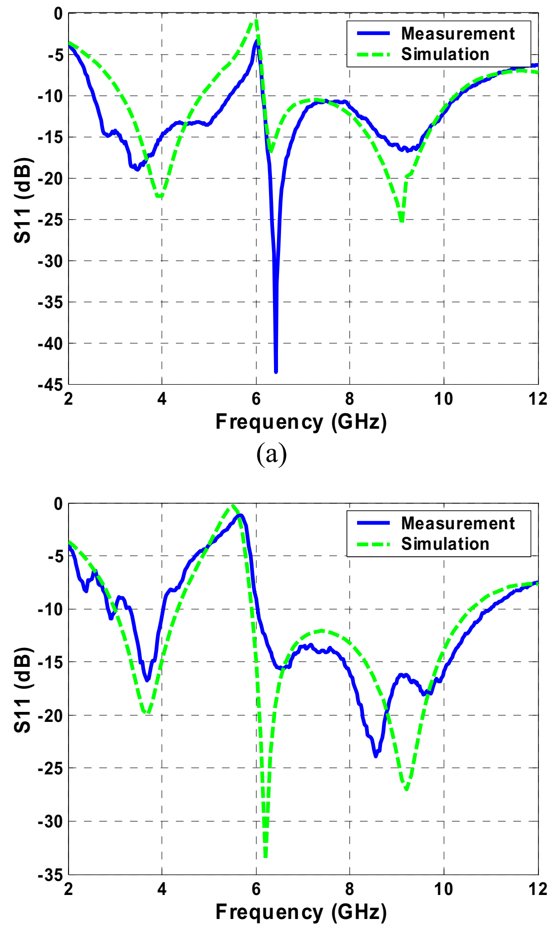


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Fig. 3. Measured and simulated return loss (a) U-shaped slot (b) C-shaped slot

III. Discussion of Measurements and Simulation Results

A. Return Loss and VSWR

For return loss and radiation pattern measurements, an SMA connector was 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. The simulated results are in good agreement with the measured results. In both cases there are two resonating frequencies around 4 GHz and 9 GHz respectively. Those two resonances are due to the ground size and the ellipse axes as explained in [10]. The presence of a slot of total length approximately λ/2 at 5.8 GHz [11] creates the frequency notch in the return loss. The longer the slot length is the lower the frequency notch shifts. Since the total length of

TABLE I

ANTENNA DIMENSIONS

D1	32.00 mm	d	0.84 mm
D2	26.80 mm	Cw	5.40 mm
L1	17.60 mm	Cl	8.10 mm
L2	9.68 mm	O	4.97 mm
S1	10.38 mm	δ	2.00 mm
S2	8.94 mm	R	3.85 mm
W	2.75 mm	Co	6.97 mm
s	0.18 mm	H	6.38 mm
D1	32.00 mm	d	0.84 mm
D2	26.80 mm	Cw	5.40 mm

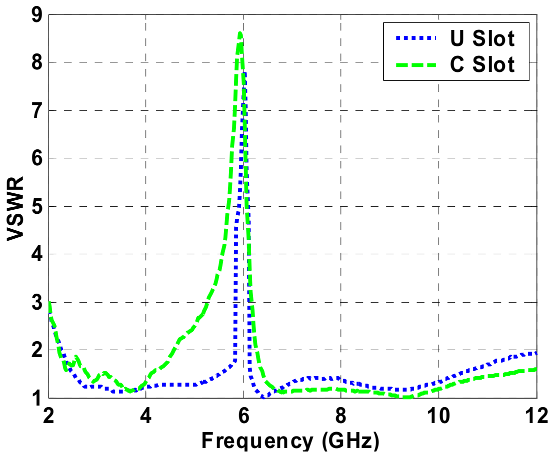
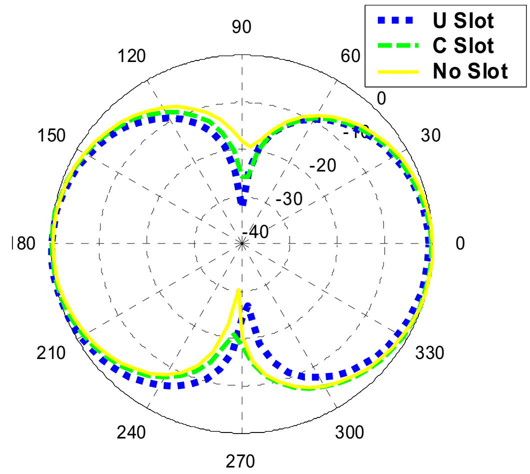


Fig. 4. VSWR measurement

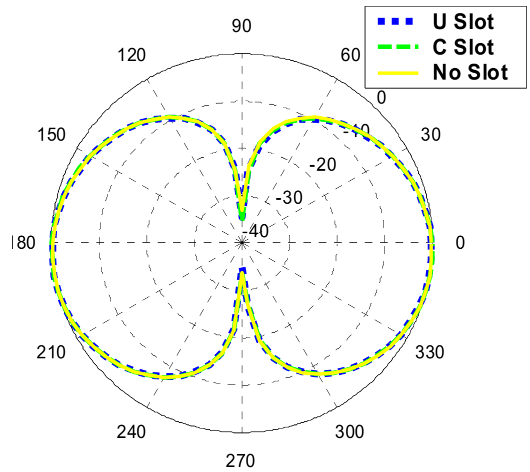
the C-shaped slot is bigger than the U-shaped slot the central frequency of the frequency band with return loss greater than -10 dB is positioned at a lower frequency as can be clearly seen in the VSWR measurement for the two prototypes, presented in Fig. 4. Although the total length of the slots is similar their effect on the return loss is not identical. The C-shaped slot causes a more broadband frequency notch compared to the U-shaped slot. Although a wider rejection band is not necessary to cover the band from 5.15-5.825 GHz limited by IEEE 802.11a and HIPERLAN/2, it gives potential for new UWB antenna designs with reconfigurable sub-bands.

B. Radiation Patterns and Gain Results

The E and H plane simulated radiation patterns at 3.3 GHz and 7 GHz are presented for the two prototypes and an antenna model without any slot to show the effect of the slots on the radiation patterns. The selected frequencies, at 3.3 GHz and 7.0 GHz, are representative of the entire UWB band. Measurements will be available for presentation at the



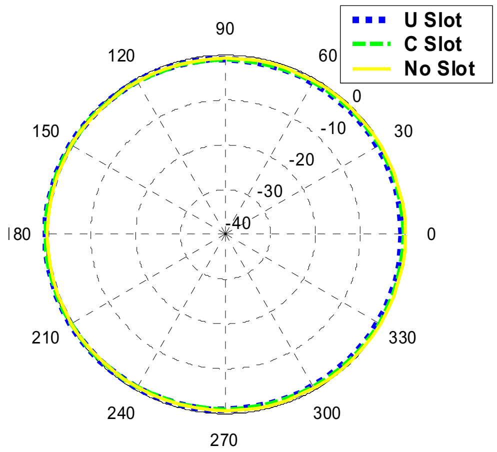
(a)



(b)

Fig. 5. E plane (x-z) radiation pattern (a) f = 3.3 GHz (b) f = 7 GHz

conference. As can be seen in Fig. 5 and Fig. 6 where E and H plane patterns are depicted respectively, the presented radiation patterns almost coincide proving that the presence of a slot does not affect the behavior of the radiation pattern. E plane is the x-z plane and H plane is the y-z plane with reference to the antenna orientation defined in Fig. 2. In the H plane the pattern has omni-directional shape for both frequencies while in the E plane there is a null in the feed line direction ($\theta=90^{o}$) which is parallel to the x axis. The slot presence though, affects significantly the total gain of the antenna. Fig. 7 shows the total gain of the antenna in dBi, in the z axis direction. It can be seen that for the frequency notch band the gain is negative, which is expected based on the return loss and VSWR measurements.



(a)

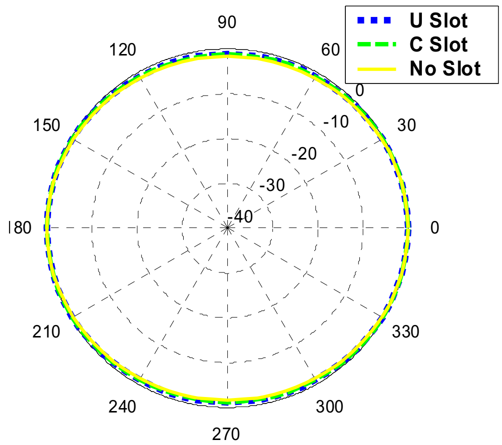


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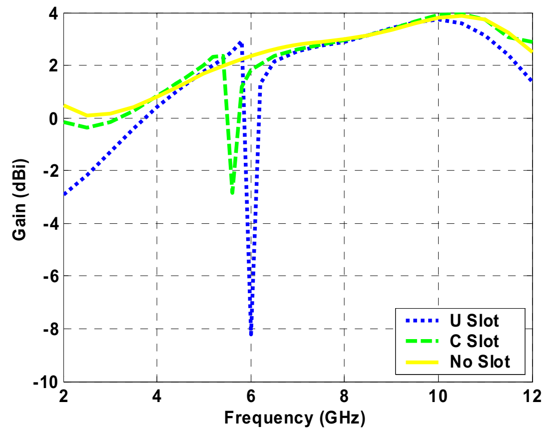
Fig. 6. H plane (y-z) radiation pattern (a) f = 3.3 GHz (b)

IV. Conclusion

Two CPW-fed UWB elliptical monopoles with band rejection characteristic on ultra thin substrate were presented. The band rejection characteristic is caused by the presence of an approximately λ/2 slot at 5.8 GHz. The fabricated prototypes used a U-shaped slot and a C-shaped slot respectively. The C-shaped slot resulted in a frequency notch band with significantly increased bandwidth that can be potentially used for the design of UWB antennas with reconfigurable sub bands. While the introduced slots have different impact on the return loss, they have similar effect on the radiation patterns. Both designs do not compromise the radiation patterns' performance and consequently the patterns remain omni-directional with consistent shape and gain characteristics.



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