Compact Cactus-Shaped Ultra Wide-Band (UWB) Monopole on Organic Substrate

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Abstract: The implementation of a novel cactus-shaped monopole antenna that demonstrates an easily controllable return loss and omni-directional radiation patterns in frequency range from 2.9 GHz up to 12 GHz that exceeds the designated ultra wide band (UWB) range is discussed in this paper. The effect of the geometry characteristics on the return loss behavior is briefly explained. The proposed prototype antenna is fabricated on 225 μm thick Liquid Crystal Polymer (LCP) with overall board dimensions of 28 mm x 32mm.

I. Introduction

The Ultra Wide Band (UWB) [1] protocol using the spectrum from 3.1 GHz to 10.6 GHz is a new promising technology suitable for high rate communications in small distances. As a result, the design of compact UWB antennas has attracted a lot of attention in recent years. The fat monopole solution was proposed by some researchers [2-3]. A different approach, the multi-segments broadband antennas proposed in [4-5] do not cover the whole UWB range. In this paper, a compact cactus-shaped monopole is proposed on a Liquid Crystal Polymer (LCP) substrate is matched in a frequency range (2.9-12 GHz) that exceeds the UWB range. The novel antenna design and the radiation principles allow an easily controllable return loss.

II. Antenna Design and Fabrication

The cactus antenna was fabricated on 225 μm thick LCP (ε_r=3, tanδ=0.002) with overall board dimensions 32 x 28 mm^2. A 225 μm thick substrate is constructed from two 100 μm substrates that are stacked and thermo bonded using one 25 μm thick, lower temperature melting point LCP. Standard photolithography is used for printing the antenna on the LCP substrate. The prototype schematic is presented in Fig. 1 and its dimensions are summarized in Table 1.

The CPW center conductor width W is 1.78 mm and length d2 is 7.92 mm. A linear taper is used to reduce the center conductor width to d=0.61 mm and is connected to the cactus-shaped stub at distance d1=10.24 mm from the board edge. The two rectangular ground patches have dimensions Gl x Gw which correspond to 9.44 mm and 14.89 mm respectively. For the primary radiator, a cactus-shaped stub is used. It consists of a semi-annular ring with inner radius r=2.60 mm and an outer radius R=5.72 mm and three linear segments of different

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lengths. The middle linear segment, L2, is 13.00 mm long and W2 is 2.08 mm wide while the left and right segments are L1= 7.28 mm and L3=1.56 mm long respectively. Both of them are 3.12 mm wide. From the bottom part of the semi-annular ring, a circular sector is detached leaving a chord of length S=2.73 mm. The overall board dimensions for the cactus antenna is 32 mm x 28 mm resulting in one of the most compact UWB antenna designs.

III. Discussion of Measurements and Simulated Results

For simulation and optimization of the prototype Ansoft HFSS [6] is used. The simulated and measured return loss for the proposed cactus antenna is presented in Fig. 2. It demonstrates return loss below -10dB from 2.9 GHz to 12 GHz that overlaps the designated UWB range. Three resonances dominate the return loss at 3.7, 5.1 and 6.4 GHz, one for each linear segment. Generally the longer the stub is, the lower the corresponding resonance appears. This can be seen in Fig. 3a where the simulated S11 is plotted for 4 different length values (L3) of the shortest linear segment. The shortest linear segment controls the higher frequency (6.4 GHz) and the previously mentioned trend is verified. The return loss shape and behavior can thus be easily controlled simply by changing the length of the linear segments (L1,L2,L3). The matching at the higher frequencies is controlled by the rectangular ground patches width Gw as can be seen in Fig. 3b where S11 is plotted for four different Gw values. It is obvious that the width of the ground patch cannot be smaller than 14.89 mm without compromising the matching in higher frequencies, although it would be highly desired for narrower and therefore an even more compact design.

Simulated and measured radiation patterns for the proposed antenna at 5 and 9 GHz, which are representative of the patterns across the frequency range, are presented in Figs. 4 and 5. Fig 4 presents the E plane (x-z) co-polarization, where $\theta=0^o$ corresponds to z-axis and $\theta=90^o$ corresponds to the x-axis. It is seen that the E-plane has a null along the x-axis because of the feed line presence, and based on the three dimensional simulation results, the pattern is relatively symmetric around the x-axis. The H plane (y-z) co-polarization plots are presented in Fig. 5, where $\theta=0^o$ is the z-axis and $\theta=90^o$ is the y-axis. It is seen that the H plane patterns for the antenna under test are almost perfectly omni-directional for both frequencies, at 5 GHz and at 9 GHz.

IV. Conclusion

A compact, cactus-shaped monopole on an organic material (LCP) suitable for integration with other passive and active components is introduced and proposed for the UWB range. The presented antenna has omni-directional radiation patterns and this characteristic remains consistent with frequency. Return loss measurements verify that the proposed antenna is well matched in a frequency band that overlaps the FCC designated UWB range while the antenna size is kept very small. All return loss and radiation pattern measurements are in very good agreement with the simulated results. The antenna on LCP is conformal, can be easily fabricated with relatively low cost and is a good candidate for a big number of mobile handheld devices.

References:

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Table I: Cactus-shaped antenna dimensions

D'1	32.00 mm	L1	7.28 mm
D'2	28.00 mm	L2	13.00 mm
Gl	9.44 mm	L3	1.56 mm
Gw	14.89 mm	W1	3.12 mm
d1	10.24 mm	W2	2.08 mm
d2	7.92 mm	W3	3.12 mm
R	5.72 mm	S	2.73 mm
R	2.60 mm	d	0.61 mm
		W	1.78 mm

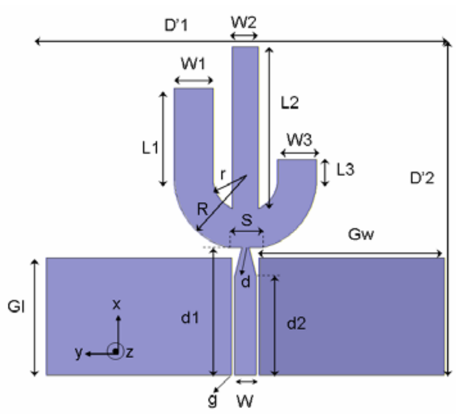

Fig. 1: Antenna Schematic

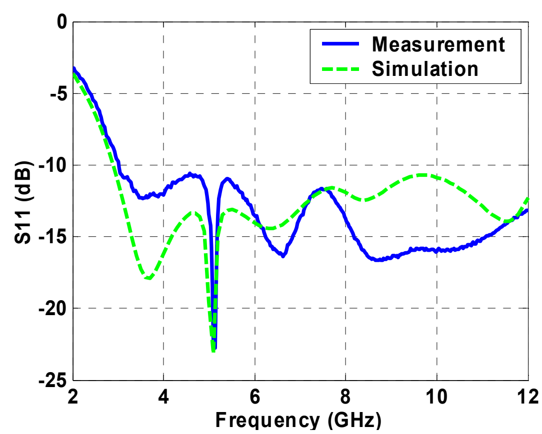

Fig. 2: Return Loss S11

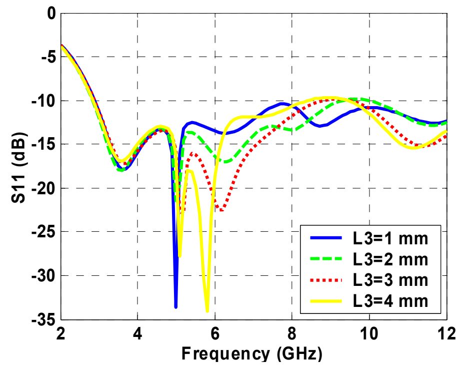

Fig. 3a: S11 with L3 variation

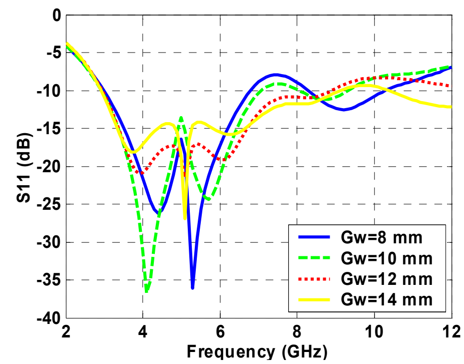

Fig. 3b: S11 with Gw variation

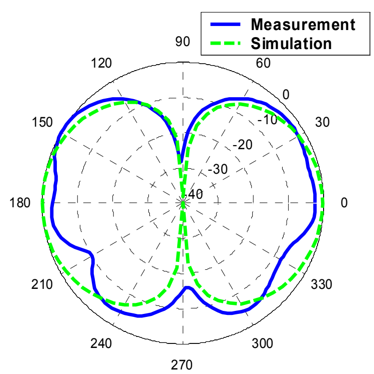

Fig. 4a: E-co at 5 GHz

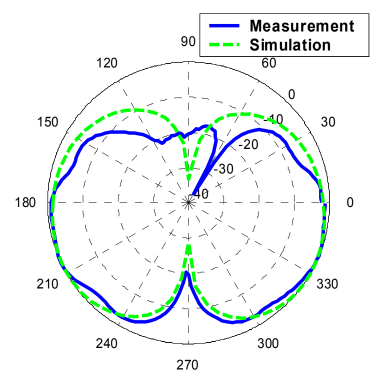

Fig. 4b: E-co at 9 GHz

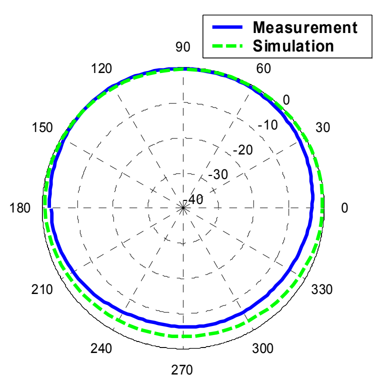

Fig. 5a: H-co at 5 GHz

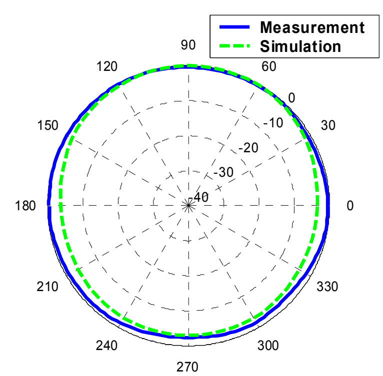

Fig. 5b: H-co at 9 GHz