A Novel Printed Stub-loaded Square Helical Antenna

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***Abstract* — A novel planar printed stub-loaded square helical (PSLSH) antenna is presented for 2.4GHz WLAN applications. Unlike conventional stub loaded helical (SLH) antennas, the input impedance of the proposed antenna is real. Therefore, a simple quarter-wave transformer can be used to match this antenna. Simulation results show that the antenna has a maximum gain of 10 dBi, a front-to-back ratio of 12dbi, a 70º half-power beam width and a good axial ratio. The volume of PSLSH antenna is 75% less than conventional axial mode helical antennas and 17% less than SLH antennas. Furthermore, the usable bandwidth of PSLSH antenna (46%) is significantly higher compared to SLH antenna (10%).**

I. Introduction

Typical axial mode conventional helical antennas (CHA) feature a high gain, a wide bandwidth, a good axial ratio and circular polarization [1]. Due to these characteristics they have found applications in various communication technologies. However, the physical size of these antennas becomes considerably large at lower frequencies and requires a strong mechanical support.

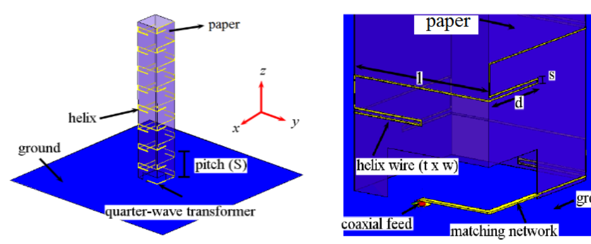
The size of CHA can be significantly reduced by regularly placing radial stubs along the circumference of the helix without affecting its radiation characteristics [2]. The stub wires are closely spaced; therefore, any radiation from them cancels out and does not contribute towards the overall radiation pattern [2]. Although stub loaded helical (SLH) antennas are more compact than CHA, they have a number of disadvantages as well. Firstly, unlike CHA, an SLH antenna has a frequency-dependent complex input impedance [2]. Hence, a simple tapered matching network cannot efficiently match the antenna to a 50Ω system over a wide bandwidth [3]. Secondly, the construction of SLH antenna is complicated and requires custom tooling [3] leading to an increased fabrication cost.

An axial-mode CHA can be approximated by a square helical antenna (SHA) with a perimeter equal to one wavelength (λ_c) at the operating frequency [1][4][5]. Its square cross-sectional geometry makes it a more suitable choice for an on-chip antenna than CHA. Moreover, it is relatively easier to fabricate and requires less simulation time than CHA [6].

The novel printed stub-loaded square helical (PSLSH) antenna presented in this paper combines the advantages of both CHA/SHA and SLH antenna types. A proof-of-concept prototype of the proposed antenna is printed on a thin paper substrate (ε_r= 2.2) using an inkjet printer, which also provides mechanical support to the helical structure. In contrast to an SLH antenna, stubs are placed in the plane of the square helix. Thus the construction of PSLSH antenna is much simpler than an SLH antenna.

II. Antenna Design and Operation

An 8-turn PSLSH antenna with four stubs per turn is shown in Fig. 1a. The antenna is constructed by printing the required helix structure on a paper substrate and then joining the two vertical edges of the sheet throughout their length. The thickness of the substrate is low (220µm) which helps mitigate dielectric losses. The substrate provides mechanical support for the antenna but also marginally decreases the antenna size and improves the axial ratio at wider angles [7]. A 6.4 × 6.4 cm copper sheet is used as the antenna reflector.



(a) (b)

Fig. 1 (a) Geometry of 8- turn PSLSH antenna (b) zoom-in details of the antenna geometry with w = 0.2mm, t = 35um, s = 0.5mm

The stubs increase the electrical length of the antenna; therefore, a significant antenna size reduction is achieved by increasing the stub length (*d*). The proposed antenna has only four stubs per turn. Although more stubs can be added per turn, it does not further improve antenna radiation characteristics or provide a further size reduction [2]. The stubs are placed far apart from the helix wires ($s \ll p$) so that their fields do not affect the antenna radiation pattern. The mutual coupling between the stubs' fields is minimized by placing them on different planes of PSLSH antenna as shown in Fig. 1b. Optimal radiation characteristics for PSLSH antenna are obtained with a turn spacing ($S_\lambda = 4 \times$ p) between

$0.09\lambda_c$ and $0.12\lambda_c$ for all stub lengths. Maximum gain was realized for $S_\lambda \approx 0.1$. The helix pitch (S_λ) for PSLSH antenna is one half of that of CHA and equal to that of SLH antenna.

The input impedance of the PSLSH antenna is real over a wide bandwidth; therefore, a simple quarter-wave transformer can be used to match the antenna with a 50Ω coaxial cable [8]. A portion of the substrate is can be etched out near the feeding point, as shown in Fig.1b, to add the matching network.

III. Simulation Results and Discussion

The 2.4GHz PSLSH antenna prototype was modeled and analyzed using Ansoft HFSS. The maximum stub length is limited to $0.65l$ in order to limit the computational complexity. The total perimeter for PSLSH antenna without stubs is $0.7\lambda_c$ which is smaller than CHA ($0.89\lambda_c$) and SHA ($0.9\lambda_c$). The apparent reduction in antenna size is due to the paper core, which increases the electrical length of the antenna and marginally reduces the useful bandwidth. But since helical antenna is inherently broadband, this does not cause a serious concern. The bandwidth of PSLSH antenna does not significantly vary for different stub length as shown in Fig. 2.

The perimeter of the PSLSH antenna is almost one half of CHA for a $0.65l$ stub length (see table 1). Therefore, the total volume of the antenna is reduced by 75% and 17% as compared to CHA and SLH antenna, respectively, for the same number of turns.

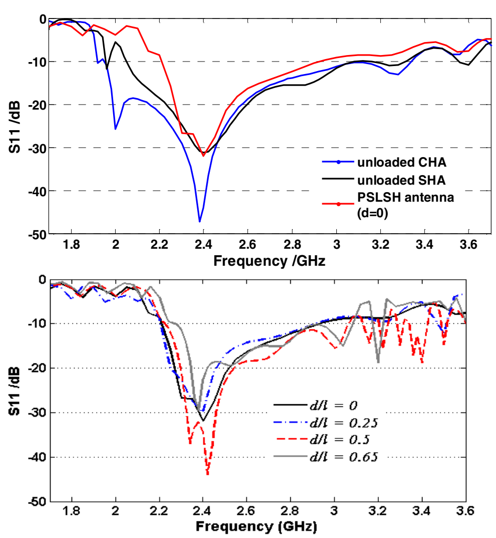


Fig. 2 Return loss of standard helical antennas (above) and PSLSH (below)

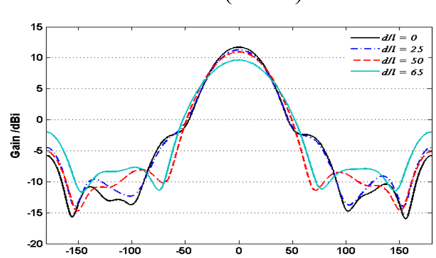


Fig. 3 Radiation pattern of PSLSHA for different stub lengths

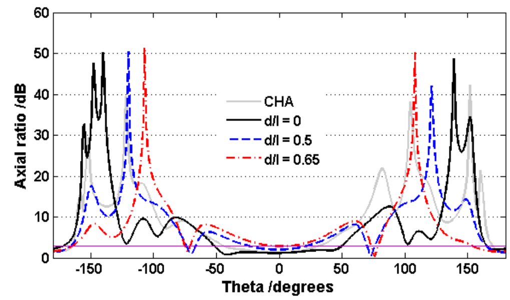


Fig. 4 Axial ratio of PSLSHA for different stub lengths

IV. Conclusion

A novel printed stub-load helical antenna has been presented in this paper along with simulation results featuring a real input impedance over a wide frequency range. The size and the bandwidth of the presented antenna can be significantly reduced compared to conventional antennas by increasing stub length without drastically affecting antenna gain and axial ratio.

TABLE I. Axial Ratio, Gain, Perimeter of PSLSHA.

Stub length (d/l)	**Axial ratio (dB)**	**Max Gain (dBi)**	**Perimeter**
0 (SHA)	1.2	11.75	0.7
0.1	1.4	11.5	0.675
0.2	1.75	11.25	0.66
0.3	2	11.15	0.635
0.4	2.2	11	0.61
0.5	2	10.9	0.59
0.6	2.05	9.75	0.54
0.65	2.88	9.6	0.52

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