Design and Analysis of a Novel Dielectric Loaded Helical Antenna for WLAN Applications

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1.0 Introduction

Helical antennas have been popular antenna configurations for various applications for its simple structure [9-10]. This paper describes the study on the best custom shape dielectric loaded helical antenna for Access Point WLAN IEEE 802.11 b/g 2.4 GHz to 2.48 GHz applications. This paper presents the investigation of a Novel helical antenna incorporated with Barium Strontium Titanate (BST). Methods and antenna assembly techniques are based on previous works[1-5].

This paper focuses on the parametric study of such antennas with the use of simulation tools using the CST Microwave Studio. The antenna impedance is optimized by varying the antenna geometrical parameters [14-15] and the dielectric loading [11] with the transient solver. The antenna design is optimized for operation with two of the WLAN Access Points (APs) already available in the market to determine its suitability for integration, as to provide an alternative to the manufacturersô antennas.

BST is a ferroelectric material. It has the potential to overcome all the limitations of MEMS, ferrite and MMIC phase shifters because it has an electric tunable dielectric constant [16]. It combines the low-loss properties of BST at microwave frequency with the distributed transmission line philosophy of the MEMS phase shifter which provides wide bandwidth and ease of design. BST was known to be a solid solution perovskite with a field-dependent permittivity and has been used in RF and microwave applications in the recent years [17].

High dielectric constant of BST would superbly reduce the dimension of the shaped required and decrease the helical antenna overall size. Other interesting aspects of BST are of its low dielectric loss, low leakage current, low temperature coefficient and the composition-dependent Curie temperature [18]. In a way, when fabricating BST into any shaped mould, heat applied would increase the dielectric constant from a few hundreds to thousands. This might happen due to the structure change from tetragonal to cubic perovskite structure involved.

2.0 Antenna Design

The geometry of dielectric loaded helical antenna, which operates at 2.45 GHz 2.48 GHz, is shown in Fig. 1(a) and its dimension in Table 1. Helix was constructed using copper wire with diameter of 1.63 mm. One important design step is to calculate the desired resonant frequency using equation (1) by manipulating the cylindrical height, D_H. The resonant frequency, f_0, (in GHz) which is a function of the resonator diameter, D_R, and length, D_H,

$$f_0 = \frac{8.553}{\sqrt{\varepsilon_r}\left(\frac{\pi}{4}\left(D_H^2\right)\left(D_r\right)\right)^{\frac{1}{3}}} \qquad (1)$$

Table 1: Geometry of the dielectric loaded helical antenna.

Component	**Dimension**
Ground plane (G_R)	29.0 mm (Radius)
Dielectric load dimension (D_H x D_R)	24.0 mm (Height) x 2.5 mm (Radius)
Helix (H_H)	5 Turns (N), 1800^0 Angle, 20.0 mm (Height)

3.0 Parametric Study

Parameter sweep was conducted on three of the most influential and sensitive dimensions in the antenna design. These parameters are the dielectric height, D_H, radius of ground plane, G_R, and helix height, H_H. The 2.45 GHz to 2.48 GHz frequency was affected mostly due to the BST dielectric height, D_H. The helix height provided the gain and resonant frequency drop, while manipulating the ground plane radius affected the gain, sensitivity and bandwidth.

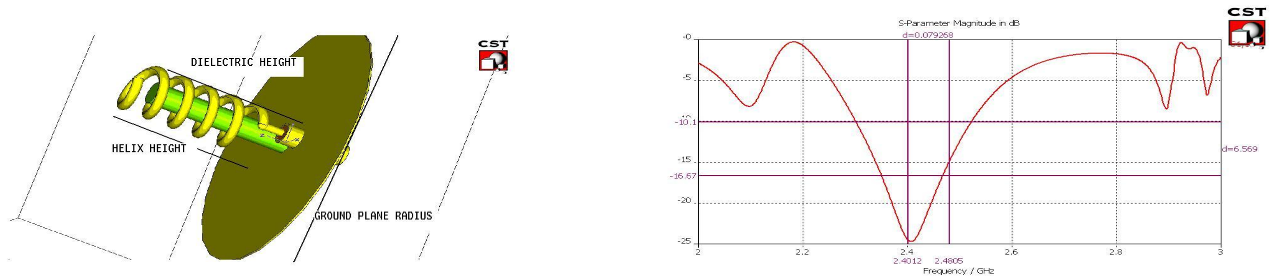
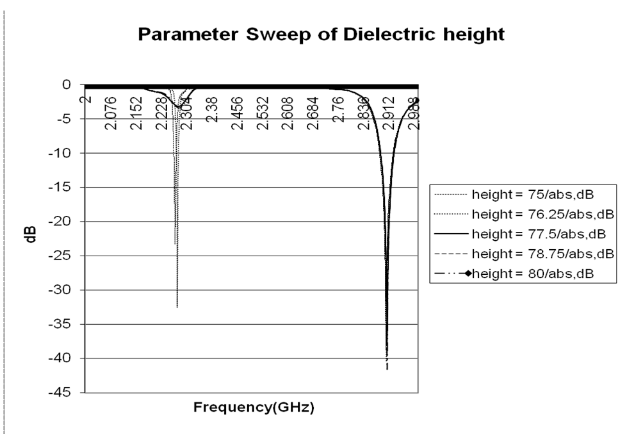
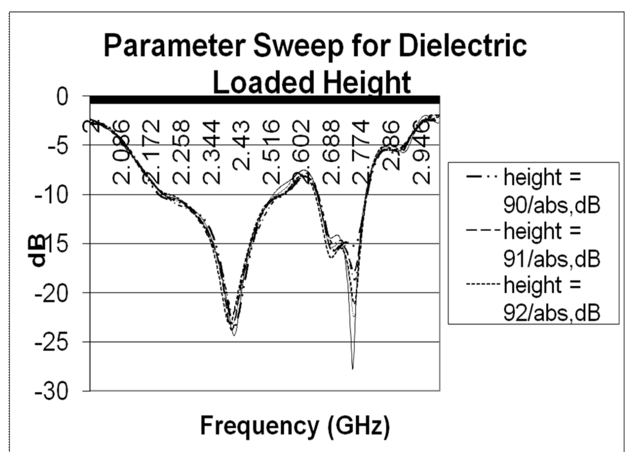


Figure 1: (a) Dimension overview of the designed antenna; and (b) S11 of antenna in the WLAN domain



(a)



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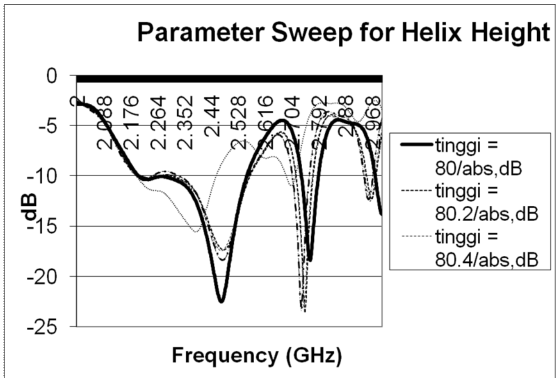


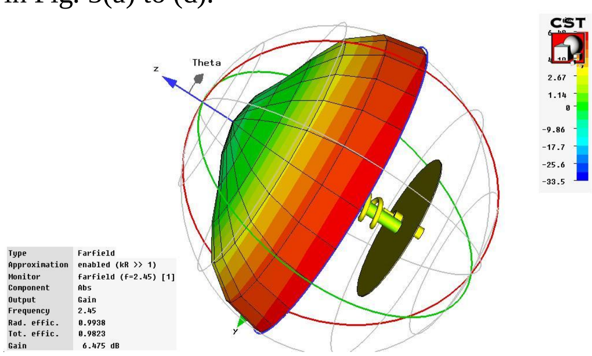
(c)

Figure 2: (a) Parameter sweep of D_H; (b) Parameter sweep of G_H; and (c) Parameter sweep of H_H

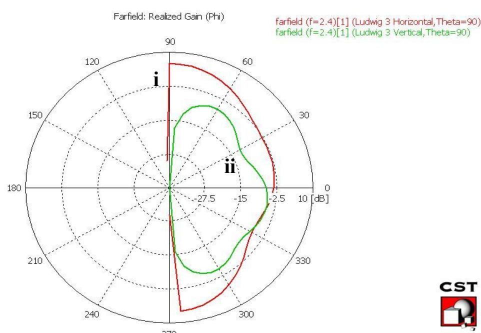
Basically, Fig. 2(a) shows the parameter sweep done on the BST dielectric height. Five samples were taken but did not meet the desired frequency and bandwidth. Fig. 2 (b) was then pursuit with five samples of the ground plane radius and it shows promising results at radius of 39 mm. Such data collected were then set as permanent dimension before proceeding to Fig. 2(c) of helix height parameter sweep. It shows at height of 80 mm, the frequency drop at 2.4 GHz to 2.48 GHz.

4.0 Results and Discussion

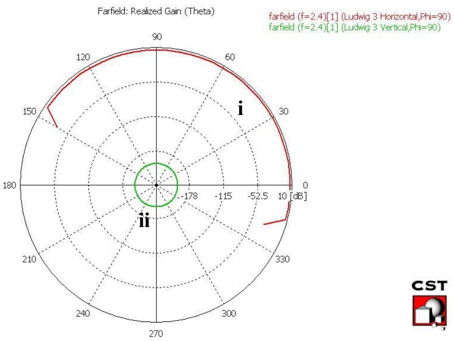
The results of dielectric loaded helical antenna return loss can be seen in Fig. 1(b) with 80 MHz bandwidth and reaching nearly -25 dB of S_{11}. The impedance simulated at 2.4 GHz is 52.55 ohm, quite higher than normal 50 ohm but can be optimized and tuned later on when fabricated. VSWR was at 1:1.129, indicating appropriately good impedance. Radiation pattern in two- and three dimensional forms are shown in Fig. 3(a) to (d).



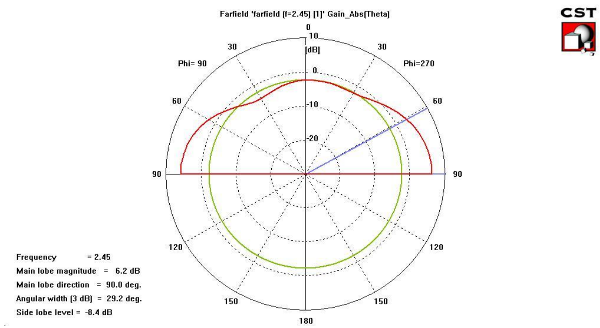
(a)



(b)



(c)



(d)

Figure 3: (a) The 3D radiation pattern; (b) H-field Co-polarization (i) and Cross-polarization (ii); (c) E-Field Co-polarization (i) and cross-polarization (ii); and (d) 3dB beamwidth from horizontal mainlobe.

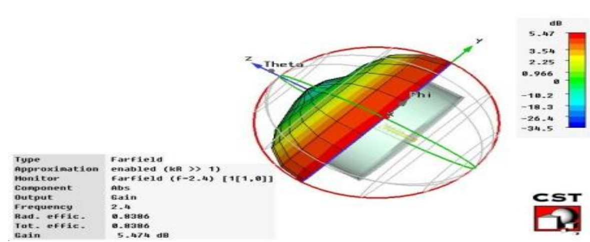
The antenna radiates at the horizontal axis, and produced a maximum gain of 6.475 dB. As can be observed from Fig. 3(d), the design also produced a narrow 3dB beamwidth of 29.2^0, which could be beneficial, especially if the antenna is applied in an indoor environment, and mounted on a ceiling or wall. To evaluate its performance when integrated with off-the-shelf APs, two sets of AP dimension measurement were taken as co-simulation subjects.

A circular 3COM MAP 385 Access Point (AP1) Fig. 4(a) and its dimension was remodeled with the dielectric loaded helical antenna inside it and simulated to find its overall performance and signal response. As expected, the results came out similarly without the AP casing except for the radiation pattern of E-Plane and H-Plane which differs in terms of its direction. The major mainlobes still are the strongest at the horizontal plane. However, the gain value dropped due to its shape and antenna placement, with a degradation of up to about 1 dB.

Another wireless AP, the 3COM 3CRWE920G73 (AP2), Fig. 4(a) which is rectangular in shape, and its dimension were remodeled with the design antenna inside as a comparison to previous simulated AP1. By far the simulation shows a better and equal performance to the antenna without the AP casing. The summary of the gain comparison between the three are shown in Table 2. With AP2 case, which is much larger in size compared to AP1, has resulted in gain and results turn out to be similar with the antenna without casing.

AP2 casing is much bigger and larger than AP1 casing. The air gap, space and plastic casing helped the antenna to radiate more. AP1 did not give the antenna much space compared to AP2. Advantage of this side way propagation is that the signal would not interfere or be in collision with other strong signal radiating at theta. This antenna performs differently by radiating mostly at its side or at azimuth level (phi). Such phenomenon occurred because of the cylinder shaped BST used as dielectric. When the helix radiates upwards from the SMA, the energy is absorbed and then release back horizontally from dielectric. It is the shape and characteristics of the BST itself that determine the overall radiation because the material can absorb high energy through the way energy is received and release it back oppositely. Thus providing alternative antenna used in a different environment.

(a)

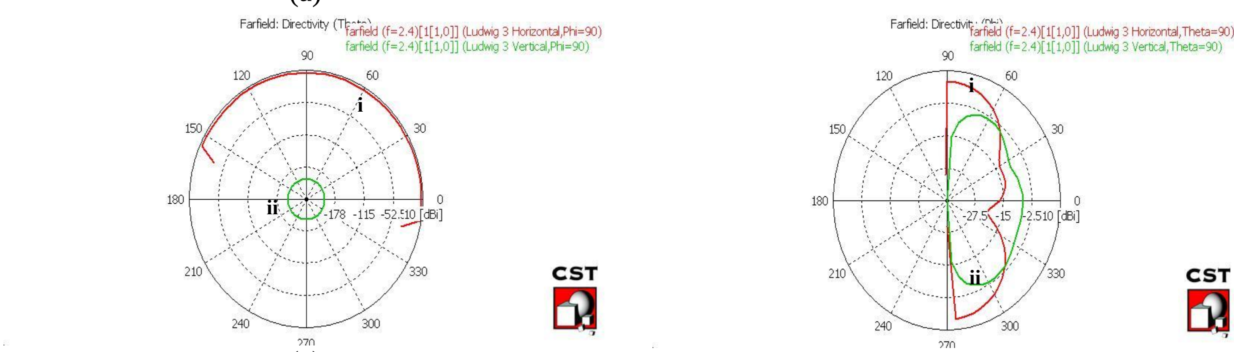


(b)

(c) (d)

Figure 3: (a) Original shape of 3Com MAP 3850 (b) 3D radiation pattern; (c) H-field Co-polarization (i) and cross polarization (ii); and (d) E-Field Co-polarization (i) and cross-polarization (ii)

(a) (b)



(c) (d)

Figure 4: (a) Original shape of 3COM 3CRWE920G73 (b) 3D radiation pattern; (c) H-field Co-polarization (i) and cross polarization (ii); and (d) E-Field Co-polarization (i) and cross-polarization (ii)

5.0 Conclusion

The dielectric loaded helical antenna created for WLAN IEEE 802.11 b/g was a success. By taking into account all the details of each component including dimensions and dielectric constant value, the result did meet up as expectation in the ISM band. To conclude, this paper has presented the ability of CST Microwave Studio in developing dielectric loaded helical antenna for WLAN applications. Having balance between theory and practice, this paper will hopefully be able to contribute significantly to the demanding needs of computer simulation requirement in the microwave industry.

Table 2: Gain comparison

Operating at 2.4 GHz	Gain (dB)
Without Access Point	6.475
With AP 1 Casing	5.474
With AP 2 Casing	6.477

6.0 References

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