Compact Conformal Dipole Antenna on Organic Substrate for 2.4 GHz Applications

Negar Tavassolian*(1), George E. Ponchak (2), and John Papapolymerou(1)
(1) Georgia Institute of Technology, Atlanta, GA 30332
(2) NASA Glenn Research Center, Cleveland, OH 44135
E-mail: negar@ece.gatech.edu

Introduction

The 2.4 GHz frequency has been used for several applications, including bio-sensing and mobile communications. These specific applications require the sensing antenna to be low cost, compact, lightweight and flexible to conform to different surfaces inside the cell phone or on the patient's body. Microstrip dipole antennas have been suggested before for this frequency applications [1]-[2]. In this paper, a microstrip dipole antenna on a flexible organic substrate is proposed. The antenna arms are tilted to make different variations of the dipole with more compact size and almost same performance. The antennas are fed using a coplanar stripline (CPS) geometry [3]. The antennas are then conformed over cylindrical surfaces and their performances are compared to their flat counterparts. Good performance is achieved for both the flat and conformal antennas.

Antenna Design and Simulation

The dipole antenna was designed and optimized at 2.4 GHz on a 200 μm thick Liquid Crystal Polymer (LCP) substrate. LCP is a low cost, organic, flexible substrate with a dielectric constant of 3.1 and loss tangent of 0.003 [4]. Microstrip dipole can be designed for its resonant frequency using transmission line model [5]. The length L of each arm is given by $L=\lambda/4$ where

$$\lambda = \frac{c}{f\sqrt{\varepsilon_{eff}}} \quad (1)$$

Where ε_{eff} is the effective dielectric permittivity, f is the frequency of operation, λ is the wavelength, and c is the light velocity. ε_{eff} for a coplanar stripline on a dielectric substrate of finite thickness is discussed in [3]. However, because of the thin dielectric substrate and its low relative dielectric constant, our initial design assumes an effective permittivity of 1. Simulations are then performed to optimize the design.

Ansoft HFSS [6] was used for the simulations. The antenna arms were then tilted from their original positions, first by 45 degrees and then by 60 degrees to form two variations of the regular dipole. The lengths of the arms are kept constant at $L = 30.175mm$ in order to maintain the operation frequency. The three antenna geometries are shown in Fig. 1 along with their dimensions.

The antennas were then fabricated using an 18 μm thick copper layer. Standard photolithography was used for printing the antennas on LCP substrate. The fast, simple fabrication allows for the antennas to be produced at very low cost. The simulated and measured return loss values for the three designs are presented in Fig. 2. Return loss

978-1-4244-2042-1/08/$25.00 ©2008 IEEE

values were measured using an 8510C Agilent vector network analyzer. To form a coaxial cable to stripline transition, the outer conductor of a coaxial waveguide was soldered to one strip conductor. The center conductor was extended across the gap and soldered to the other strip conductor. This method of feeding has been shown to provide symmetric currents [7], which are critical for antenna radiation pattern measurements. Good agreement is achieved between simulated and measured return loss values. The regular dipole has a simulated center frequency of 2.2 GHz, whereas both of the tilted antennas have a center frequency of 2.4 GHz.

The real application of the antennas requires them to be conformed to the cell phone or to the patient body. Therefore, in the next step we roll each antenna in its latitude direction around a Styrofoam ($\varepsilon_r = 1.03$) cylinder to examine its performance in the conformal state. Separate cylinders were cut with a different diameter for each antenna, so that each antenna could be rolled 90 degrees in its latitude direction. Return loss measurements are taken for these antennas. The antennas are then rolled in their longitudinal directions by 90 degrees in the same manner as described above. In this case, the end of the CPS feed is placed where the Styrofoam starts to curve. Fig 3 shows photos of the fabricated antennas rolled in the latitude and longitude directions. The return loss results for the rolled antennas are added to Fig. 2. The resonant frequency is seen to be almost independent of conforming the antenna.

Radiation Pattern Results and Discussion

Ansoft HFSS is used to simulate the radiation pattern of the flat antennas. E-plane and H-plane radiation patterns are shown in Figs. 4 and 5, respectively. Co-polarized and cross-polarized components are shown for the antennas at their center frequencies. The E-plane co-polarized component (E_co) has been rotated for the bent dipoles. The rotation is more pronounced for the 60 degree dipole. The H-plane co-polarized component (H_co) remains almost the same for all three antennas. Simulated gain values are presented in Fig. 6 versus frequency. Gain performances of the antennas also remain constant while they are folded. Measurement results for the flat and rolled antennas are in progress and will be presented at the conference.

Conclusion

A compact dipole antenna on thin, flexible LCP substrate was designed and fabricated for 2.4 GHz applications. Two variations of this antenna with 45 degree and 60 degree tilted arms were also suggested. The antennas show good performance for the 2.4 GHz frequency applications. Measured return loss values are similar for all the antennas. The E-plane radiation pattern is rotated for the dipoles with tilted arms. All three antennas were then conformed 90 degrees around cylindrical surfaces. Their return loss values showed little change compared to their flat counterparts. These results suggest that the antenna could be used just as reliably when conformed over a cylindrical surface as required by its specific application.

References:

[1] M. H. Jamaluddin, M. K. Rahim, M. Aziz, A. Asrokin, "Microstrip dipole antenna analysis with different width and length at 2.4 GHz", *IEEE Asia-Pacific Conference on Applied Electromagnetics,* Dec 2005.

[2] Chih-Ming Su, Hong-Twu Chen and Kin-Lu Wong, “Printed dual-band dipole antenna with U-slotted arms for 2.4/5.2 GHz WLAN operation”, *Electron. Letters,* vol. 38, pp. 1308-1309, May 2002.
[3] R. N. Simons, *Coplanar Waveguide Circuits Components & Systems,* J. Wiley & Sons, 2001.
[4] D.C. Thompson, O. Tantot, H. Jallageas, G.E. Ponchak, M. Tentzeris, J. Papapolymerou, “Characterization of liquid crystal polymer (LCP) material and transmission lines on LCP substrates from 30 to 110 GHz”, *IEEE Transactions on Microwave Theory and Techniques,* vol.52, no.4, pp. 1343-1352, April 2004.
[5] David M Pozar, *Microwave Engineering,* J. Wiley & Sons, 2005.
[6] Ansoft Corp. “HFSS Electromagnetic Simulator”, www.ansoft.com/products/hf/hfss
[7] J. Jordan, G. E. Ponchak, N. Tavassolian, M. Tentzeris, “Characteristics of a Linearly Tapered Slot Antenna (LTSA) Conformed Longitudinally Around a Cylinder”, *IEEE International Symposium on Antennas and Propagation,* June 2006.

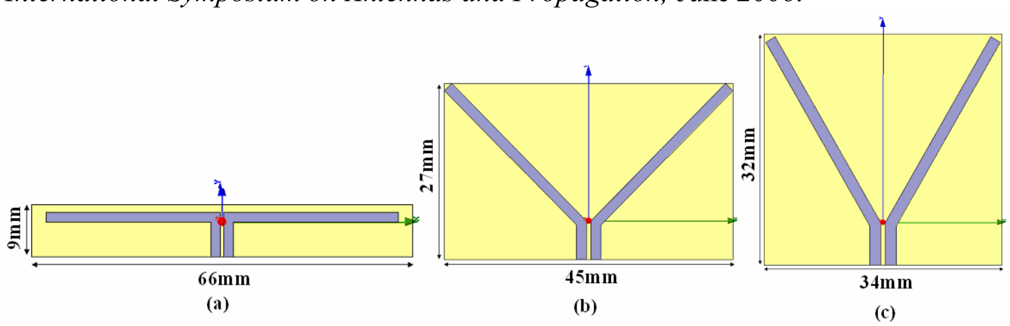


Fig. 1. Antenna geometries (a) Dipole antenna (b) 45º tilted dipole (c) 60º tilted dipole.

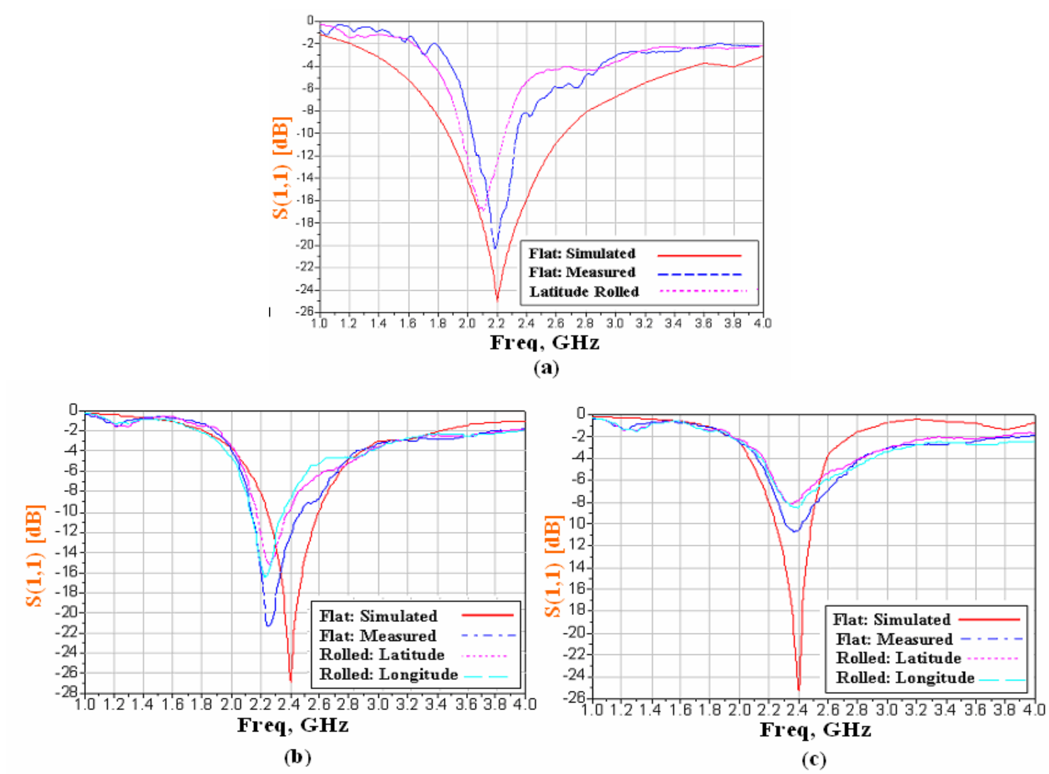
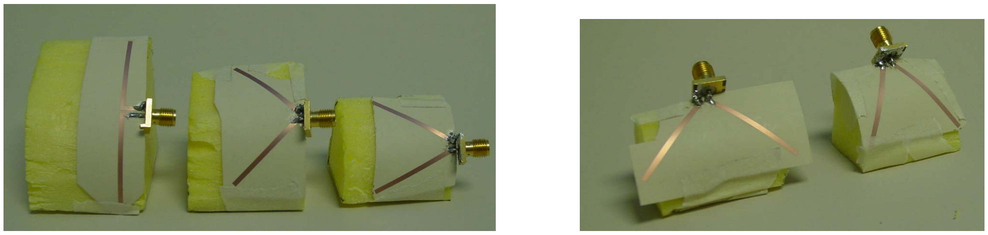


Fig. 2. Simulated and measured return loss results for the flat and conformal antennas. The regular dipole is only rolled in the latitude direction due to its small size in the longitude direction (a) Regular dipole antenna (b) 45º tilted dipole (c) 60º tilted dipole.



(a) (b)

Fig. 3. Photographs of the rolled antennas (a) Antennas rolled 90º in the latitude direction. From left to right: regular dipole, 45º tilted dipole, and 60 º tilted dipole. (b) Antennas rolled 90º in the longitude direction. From left to right: 45º tilted dipole, and 60º tilted dipole. The regular dipole is only rolled in the latitude direction due to its small size in the longitude direction.

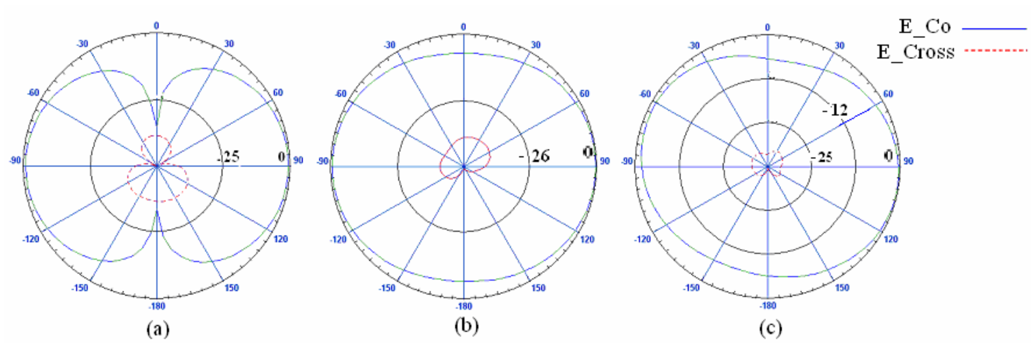


Fig. 4. Simulated E-Plane radiation patterns for the flat antennas at the center frequency (a) Regular dipole antenna (b) 45º tilted dipole (c) 60º tilted dipole.

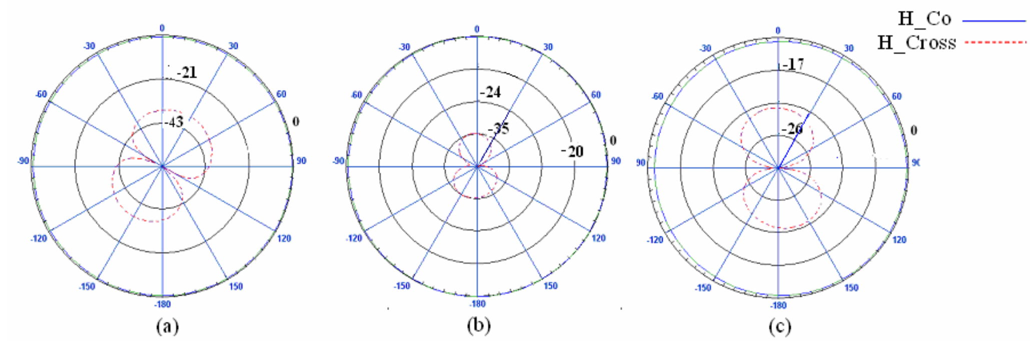


Fig. 5. Simulated H-Plane radiation patterns for the flat antennas at the center frequency (a) Regular dipole antenna (b) 45º tilted dipole (c) 60º tilted dipole.

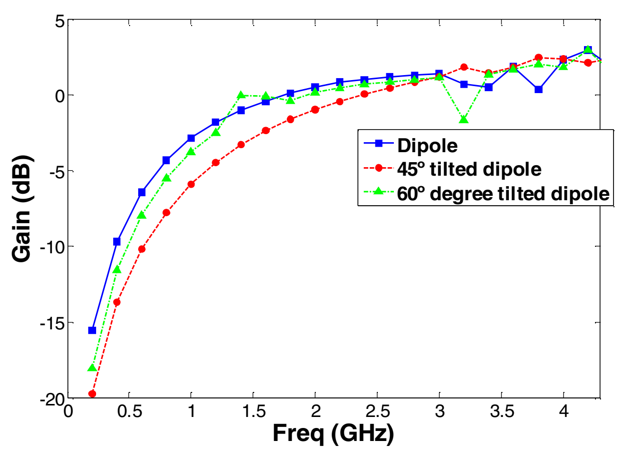


Fig. 6. Simulated gain versus frequency.