A FLEXIBLE DUAL-BAND MONOPOLE ANTENNA

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ABSTRACT
In this paper, a flexible dual-band monopole antenna had been fabricated on polyimide film. Experimental results clearly show that both the antenna bandwidth and the return loss are nearly identical while measuring at 45-degree and 90-degree bending. However, bending the antenna will change the direction of current of the antenna radiator, resulting in lower radiation energy. Hence, the maximum gain of the antenna is decreased more than 40% as the degree of curvature increases, but the maximum gain is still greater than 1dB for the antenna bended less than 90-degree. Since both the antenna bandwidth and the return loss exhibit a high tolerance on bending curvature, the flexible dual-band monopole antenna not only can be applied to the wireless communications, but also can be used on flexible display technology.

KEYWORDS: *flexible Antenna, Monopole Antenna, polyimide substrate*

I. INTRODUCTION

As wireless technologies are making rapid progress, devices with wireless application can be seen in home appliances, medical instruments and watches / garments, and the computer is no more the sole device to access the internet. The short-range wireless technologies that are widely applied and frequently seen are the followings: Bluetooth, ultra-wideband (UWB), radio-frequency identification (RFID), near field communication (NFC), etc. [1-2].

Conventionally, the substrate for making printed circuit boards (PCB) is bonded fiberglass (FR-4), which has the following characteristics: high mechanical strength in a constant temperature of 150 degrees Celsius, fine electric performance in a wet state and fire resistance. However, it has the following shortcomings: no 3D wiring, no flexibility and bad weight controllability. Recently, the soft substrate, which has the advantages of being light, thin and bendable, is used to make flexible PCB (FPC), thus further promoting application of short-range wireless technology to portable electronic devices and flexible display technology.

The frequently seen flexible substrates are composed of 4 ingredients: Polydimethylsiloxane (PDMS) [3-6], basic paper [7-8], high-frequency substrate [9] and polyimide film [10-11] with the following characteristics: PDMS requires complex equipment and processes; basic paper lacks durability in practice and is difficult to apply metal coating onto it in processes [10-11]; high-frequency substrate has wonderful properties but pretty high cost, making it not fit for mass production; and polyimide film is fit for mass production due to its merits of simple processes, high robustness and low cost. Consequently, the author decided to use polyimide film as the substrate and the copper foil tape to serve as the copper clad laminate (CCL) to fabricate the flexible dual frequency/band monopole antenna.

This paper is organized as follows. Section II descripts the structure and fundamental characteristics of the flexible antenna, then, focuses on the angle bending effect of the flexible antenna. Finally, in Section III, the conclusions and future works are drawn.

II. ANTENNA DESIGN

The antenna employed the polyimide film with dielectric constant 3.5, thickness 0.125 mm, loss tangent tanδ 0.0026 and its metal thickness 35μm. Figure 1 shows the Design parameters, where *TW=30mm, GW=13.5mm,* SW_1*=2mm,* SW_2*=1mm,* SW_3*=0.8mm,* SW_4*=1.5mm, TH=50mm, GH=14mm,* SH_1*=28.8mm,* SH_2*=11.8mm,* SH_3*=8mm,* SH_4*=7.5mm and* SH_5*=7.5mm.*

The frequency of antenna for design is the wireless band of WLAN. The antenna fed 50Ωwith coplanar waveguide (CPW). In the radiator, we divide two different resonant path. The First path use the way of Bending in order to make 1/4 wavelength of 2.4GHz band. Another path use the way of inverted-L in order to make 1/4 wavelength of 5.2GHz band. Figure 2 shows the antenna's entity.

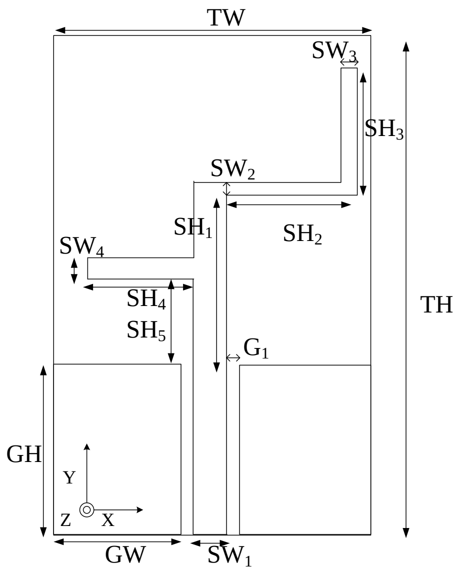

Figure 1 Design of a flexible dual -band monopole antenna

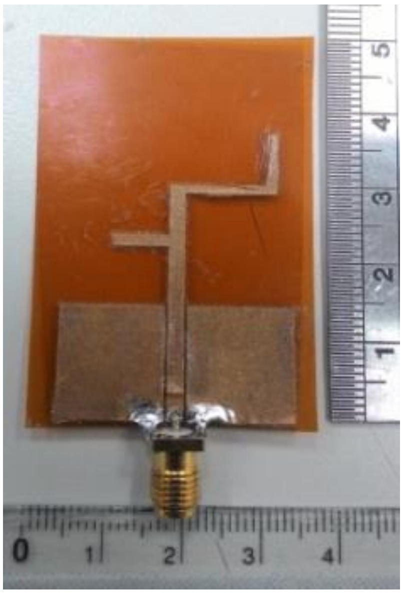

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Figure 2 flexible dual-band monopole antenna

Figure 3 indicates the reflection coefficients simulated and measured by Ansoft-HFSS, show the 2 resonant frequencies identified in both simulation and measurement. The first simulated and measured outcomes are 1.92-2.78GHz and 2.05-2.76GHz with the bandwidths 35.1% and 28.9%, respectively. The second simulated and measured outcomes are 4.61-5.69GHz and 5.0-5.58GHz with the bandwidths 20.9% and 10.9%, respectively. Regarding the reflection coefficients, offset toward high frequency was identified with a reduced bandwidth in the measured figures when compared with the simulated figures. It is inferred that the copper foil cut by the machine in need of precision caused the high-frequency offset and reduced bandwidths. Nonetheless, the figures still show that the antenna has good impedance matching.

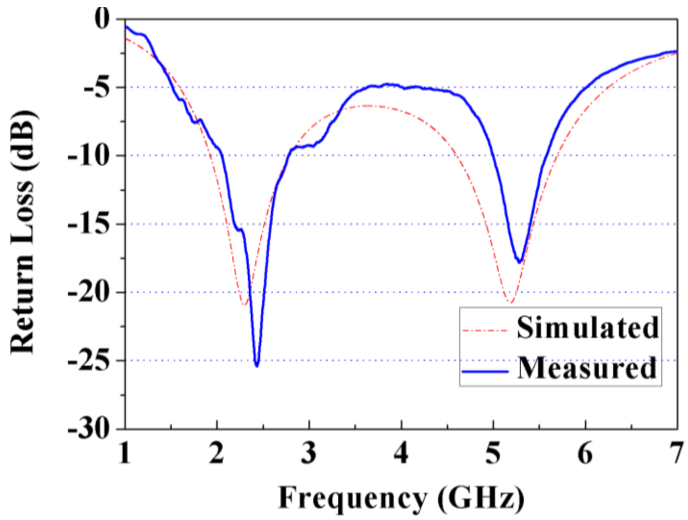

Figure 3 Measured and simulated return loss for flexible dual-band monopole antenna

Figures 4-7 show the radiation patterns of two planes at two frequencies. Figure 4 similar to the omni-directional antenna is fit for wireless devices. Figure 6 implies the similar energy in horizontal and vertical polarization due to strong horizontal component.

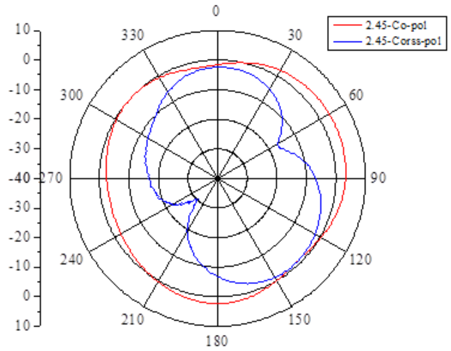

Figure 4 Measured radiation pattern of x-z at 2.45GHz

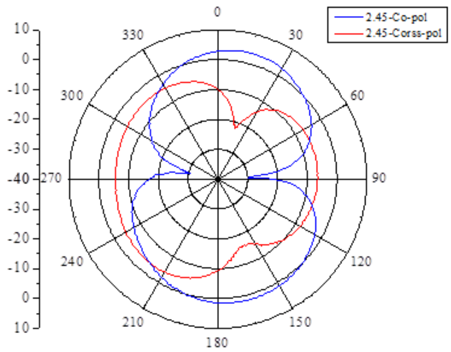

Figure 5 Measured radiation pattern of y-z at 2.45GHz

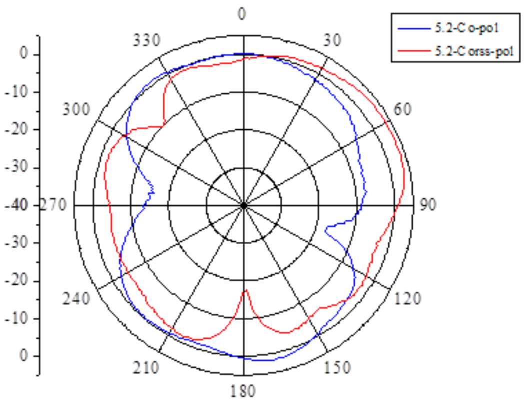

Figure 6 Measured radiation pattern of x-z at 5.2GHz

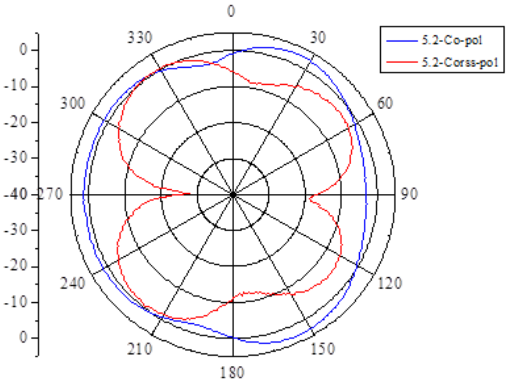

Figure 7 Measured radiation pattern of y-z at 5.2GHz

In order to discuss the angle bending for characteristic of antenna .in this paper we use 0°、45°and 90° analysis measurement of characteristic of antenna. Figures 3-7 show the measured results. Figures 8 and 9 show the schema and entity at the angles 45° and 90°, respectively.

Figure 10 shows the measured outcomes of the reflection coefficients at the bending angles. The bandwidth 2.45GHz had no significant change at 45° but had a decrease of 25.1% from 28.9% at 90°. The bandwidth 5.2GHz had no significant change at 3 bending angles. The measured outcomes prove that the author-fabricated flexible antenna with bending angles affected reflection coefficients and bandwidth in a slight manner.

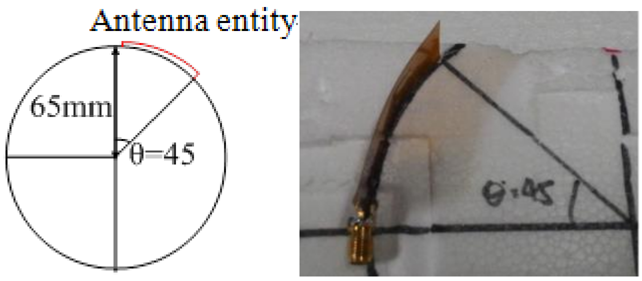

Figure 8 Schema and entity of the angle 45°

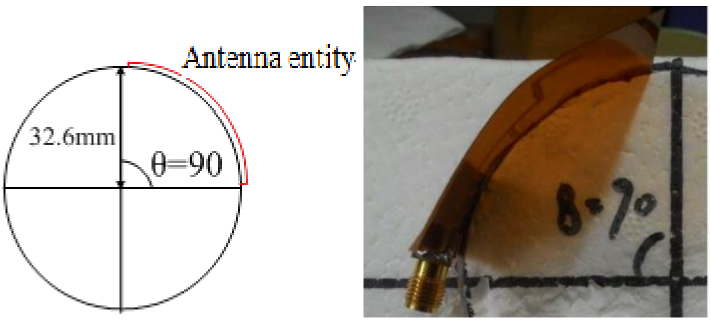

Figure 8 Schema and entity of the angle 90°

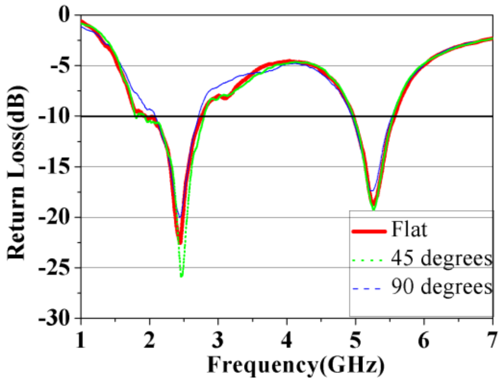

Figure 10 Measured reflection loss of variety at angles

Figures 11 and 12 shows the measured radiation patterns in 45°, Antenna of radiation patterns for bending produce more energy effect at the direction of bending plane. Figures 13& 14 shows the measured radiation patterns in 90°.It has the same trend of radiation patterns. All the 4 graphs indicate the deflection arising from the bending altering the current direction of the emitter, causing a decrease in paths equivalent to that in radiation energy. Comparison among the graph of the angle 0°, that of 45° and that of 90° showed a decrease of 40% and of 50% in the antenna's maximum gains (shown in table 1), respectively. However, the pattern of the latter has the feature of a monopole antenna.

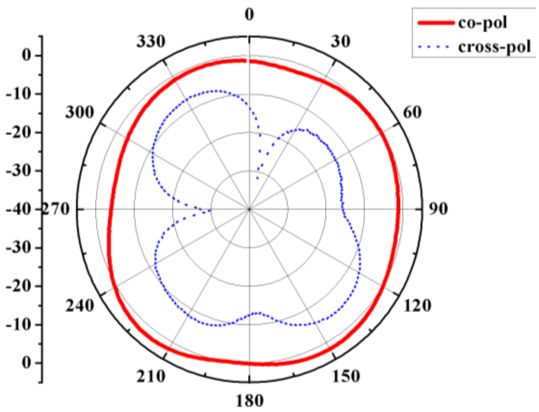

Figure 11 Measured radiation pattern of x-z in 45°at 2.45GHz

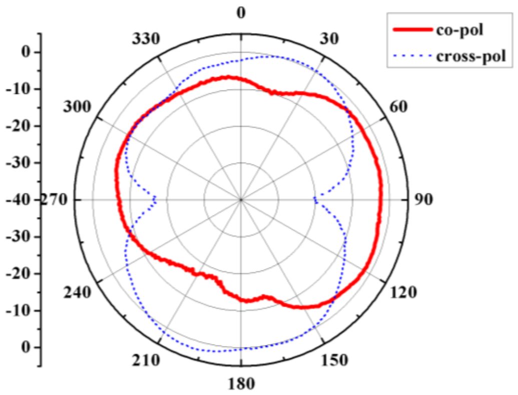

Figure 12 Measured radiation pattern of x-z in 45°at 5.2GHz

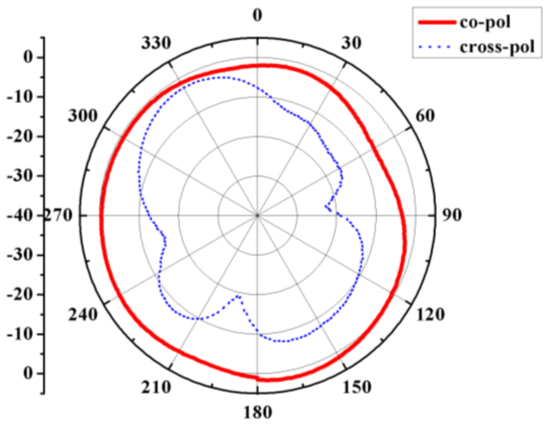

Figure 13 Radiation pattern measured of x-z in 90°2.45GHz

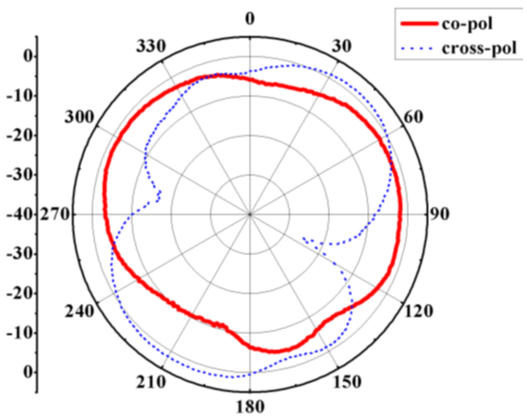

Figure 14 Radiation pattern measured of x-z in 90°5.2GHz

Table 1 Comparison of maximum gains of frequency and bending

Angle tested	Frequency measured	
	2.45GHz	5.2 GHz
0°	3.71 dB	3.55 dB
45°	2.26 dB	2.19 dB
90°	1.96 dB	1.74 dB

III. Conclusion And Future Work

In this letter, a flexible dual-band monopole antenna is presented. Use the polyimide-film flexible substrate is light, thin, bendable and robust (dielectric constant 3.5, thickness 0.125mm and metal thickness 35μm). The 3 simulated and measured bending angles aim to identify how the antenna's angularity altered its bandwidth, reflection coefficients and gains. The outcomes and remarks show that the author-fabricated flexible frequency/dual band monopole antenna with the polyimide-film flexible substrate has fine bandwidth and fine reflection coefficients at the preceding bending angles. In the future, integrating the flexible antenna with wearable products or sensors is under investigation.

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