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Flexible Circular Polarized Monopole Antenna Using EGaIn Alloy and PDMS Material

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Abstract

A flexible broadband circular polarized antenna is proposed in this paper. Liquid metal (EGaIn) is used for the top radiator and the ground plane of antenna, and PDMS is used as the substrate. The antenna has good impedance matching and circular polarization performance. The simulation results show that the impedance bandwidth is 80.4%(1.45 GHz to 3.4 GHz) and the axial ratio bandwidth is 71% (1.76 GHz to 3.7 GHz). The effects of transverse and longitudinal bending on antenna performance are analyzed, the results show that the antenna can still maintain good performance in bending state.

Keywords

EGaIn, PDMS, Flexible antenna, Circular Polarization.

1. Introduction

Circular polarized antennas are known best specially in militaries because of the terrain adaptability and offer better effective transmission results, and very useful for various application such as satellite communications, global navigation system, wireless sensor, etc… [1-3]. For a circular polarized wave, the electric field vector at a given point in space traced as a function of time is a circle. The sense of rotation can be determined by observing the direction of the field's temporal rotation as the wave is viewed along the direction of wave propagation: if the field rotation is clockwise, the wave is LHCP; if the field rotation is anti-clockwise, the wave is RHCP. [4-5].

With the development of wearable devices and intelligent wireless devices, flexible antenna has been widely concerned. EGaIn is a non-toxic liquid alloy, which is composed of 75% gallium and 25% indium[6]. It is liquid at room temperature, with excellent conductivity. Polydimethylsiloxane (PDMS) is a kind of high polymer organosilicon compound[7]. It is a viscous liquid at low temperature, which can be cured by heating and has high elasticity. The characteristics of EGaIn and PDMS are very suitable for flexible antenna.

Various flexible antennas have been reported in recent years. In article [8], a flexible dual-band conductive polymer antenna is proposed. In [9], a flexible UWB antenna using PDMS is developed, the impedance bandwidth of the antenna ranges from 2.5GHz to 12.4GHz. In [10], a flexible invert-F antenna is designed to operate at GSM 1800 MHz and ISM 2450 MHz bands. Up to now, most of the reported flexible antennas are linearly polarized, which can not meet the needs of the flexible circularly polarized antenna. In this paper, a broadband CP flexible antenna based on liquid metal EGaIn and flexible material PDMS is proposed.

2. Antenna design and simulation results

The topological structure of proposed CP monopole flexible antenna is shown in figure 2.1. The CP characteristics of antenna are mainly achieved by asymmetric feed. Through the design of sawtooth-

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shaped radiator, the antenna bandwidth is widened and the circular polarization performance is improved. Liquid metal (EGaIn) is used for the top radiation patch and the bottom ground plane of the antenna, and PDMS is used as the substrate. PDMS is also used for packaging the radiation patch and the bottom ground plate. The relative dielectric constant of the substrate PDMS is ε=2.65, and the loss tangent tanδ=0.02. The PDMS substrate has a size of 63×55 mm^2 and a thickness of 1.5mm.

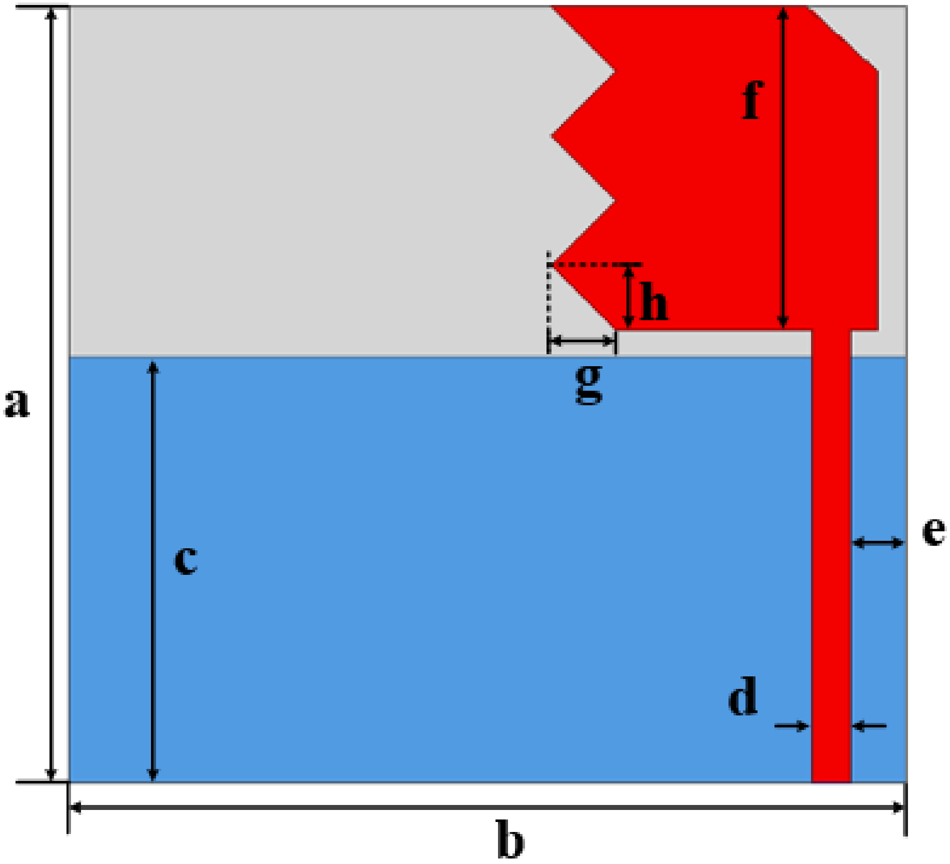

Figure 2.1. Proposed circular polarized antenna

The dimensions of the antenna are shown in table 1.

Table 1. Antenna dimensions Unit: mm

Name	Value	**Name**	Value
a	55	e	4.3
b	63	f	23
c	29	g	4.6
d	2.9	h	4.6

The CP characteristics of the antenna can be analyzed from surface current distribution. figure 2.2 shows the surface current distribution of the antenna at 2.4GHz. The direction of the radiator and ground plane surface currents is shown as a phase change from 0° to 270°. At 0° phase, the surface current of the antenna is mainly in the -X direction. At 90° phase, the surface current flows mainly in the +Y direction. At 180° phase, the main direction of the antenna surface current is +X, opposite to the direction of the surface current at 0°. At 270° phase, the surface current direction is mainly -Y. The direction of the antenna surface current changes clockwise in four phases and thus the antenna radiate left-handed circular polarized (LHCP) wave in the +Z direction.

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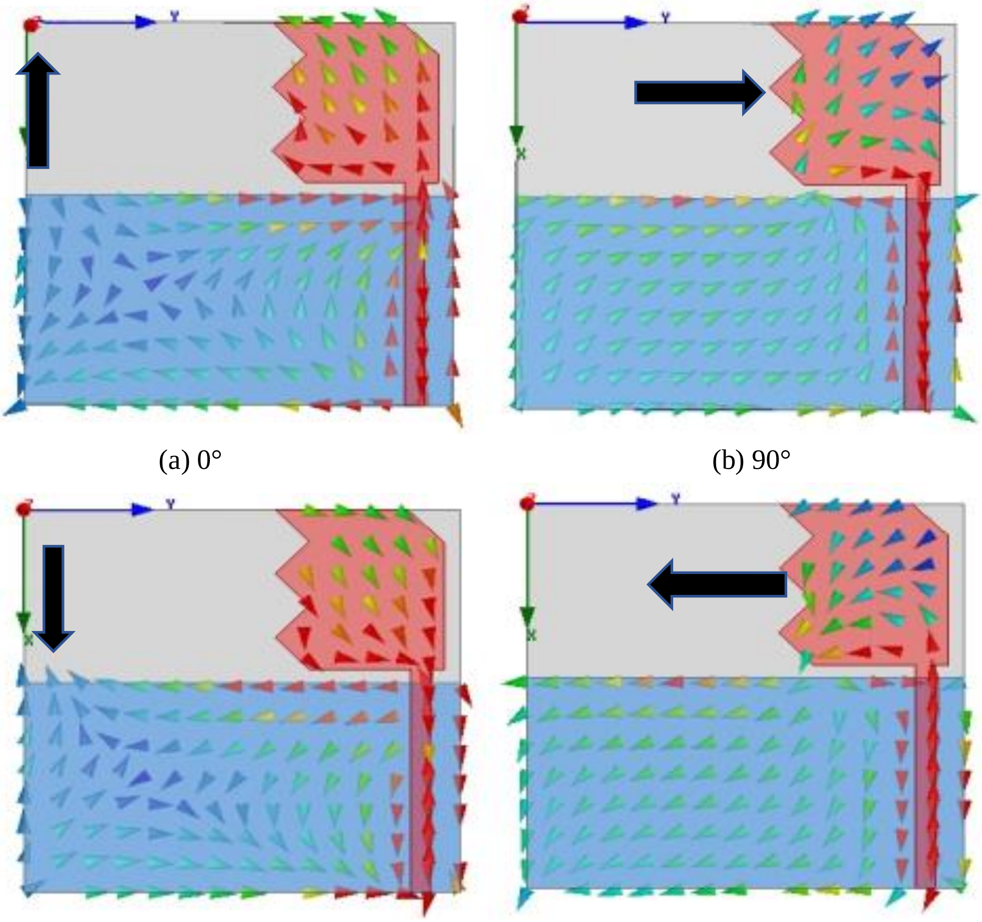

(a) 0° (b) 90°

(c) 180° (d) 270°

Figure 2.2. Surface current distribution of antenna on phase=0°, 90°, 180° and 270°

The reflection coefficient S11 of antenna is shown in figure 2.3. Reflection coefficient is the ratio of reflected wave to incident wave voltage. Generally, reflection coefficient less than -10dB is considered acceptable. The bandwidth of S11 < -10 dB is defined as the effective impedance bandwidth, in which the antenna has good impedance maching. The S11 plot shows that the antenna has a impedance bandwith from 1.45 Ghz to 3.4 Ghz.

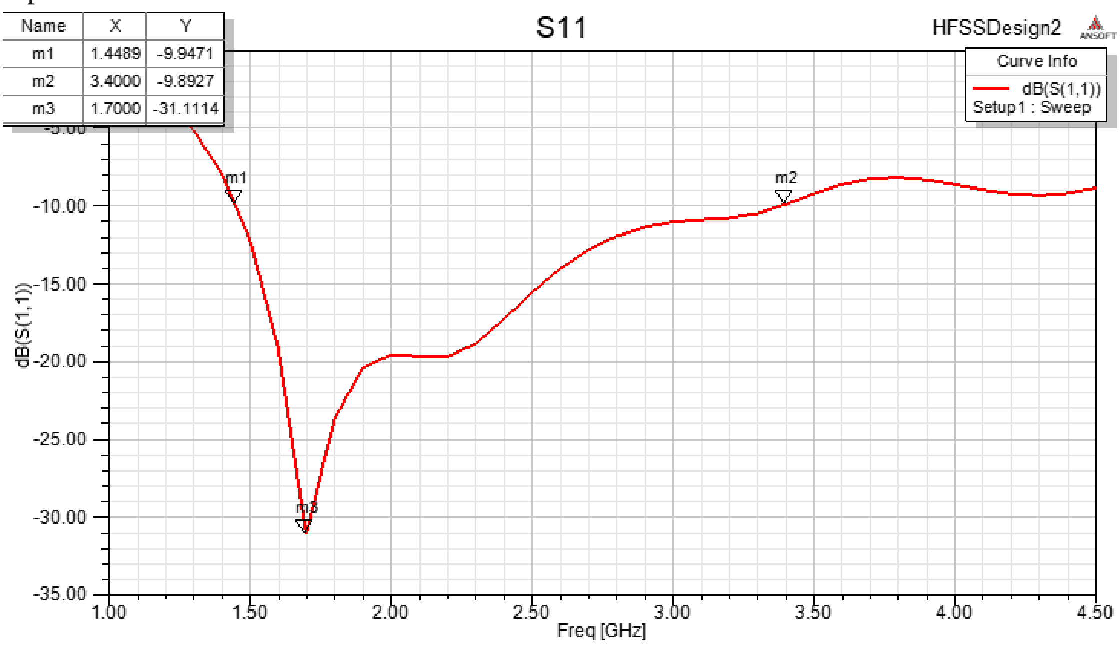

Figure 2.3. S11 parameter

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Axial ratio is an important performance parameter of circular polarized antenna. It represents the purity of circular polarized. The bandwidth that axial ratio is not more than 3dB, which is defined as the circular polarized bandwidth of antenna. From the simulation results, it can be seen that the 3dB axial ratio bandwidth is 1.94 GHz, from 1.76 GHz to 3.70 GHz.

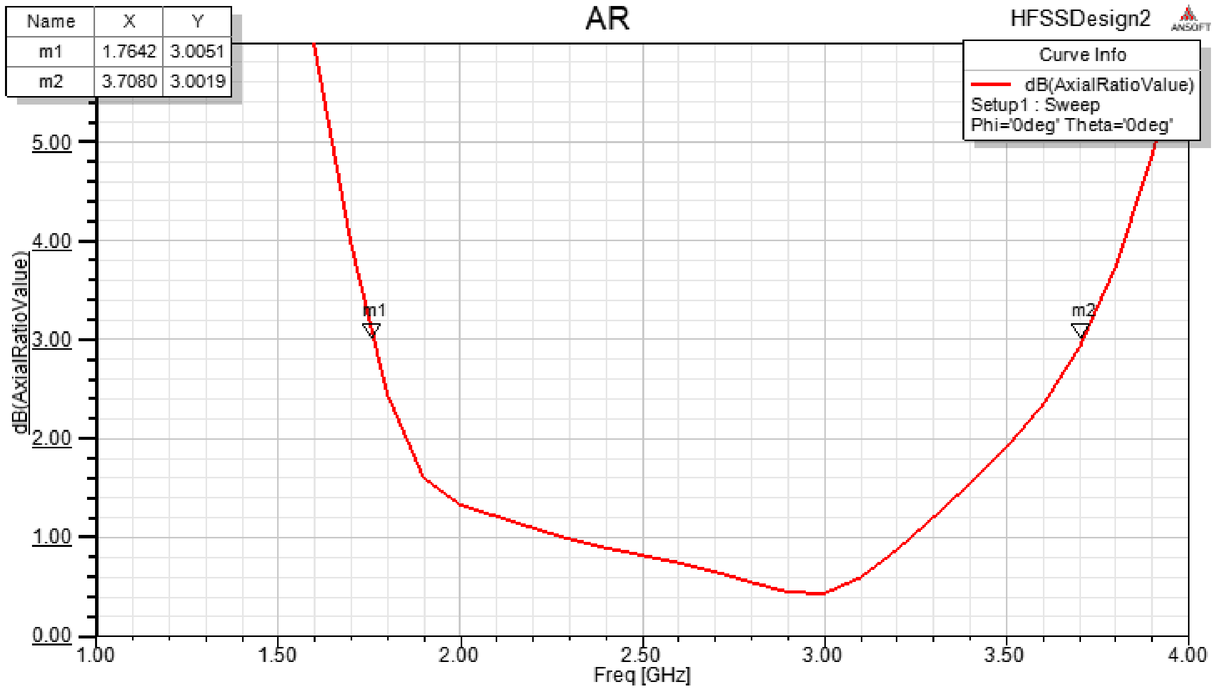

Figure 2.4. Axial ratio value

The figure 2.5 shows that the peak gain of the antenna in the working bandwidth is about 2 to 3dB, and the gain changes little in the whole bandwidth, indicating that the antenna has good radiation characteristics.

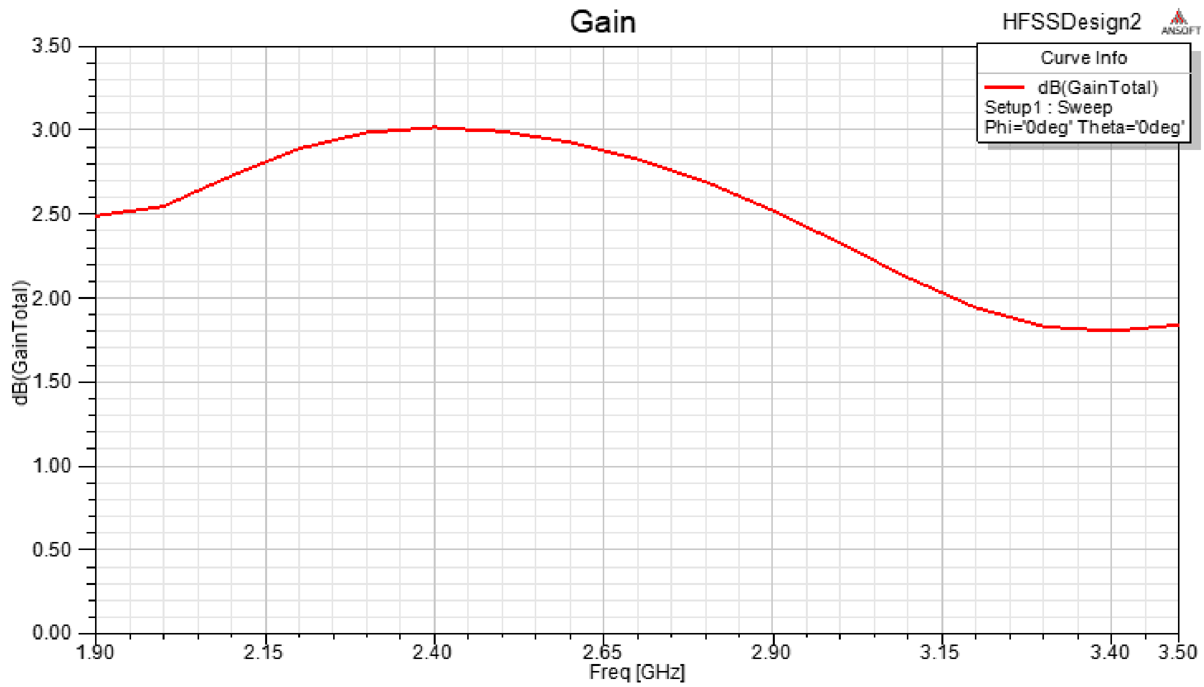

Figure 2.5. Antenna gain

The radiation pattern of XZ and YZ plane of the antenna at 2.4GHz and 3GHz is shown in Figure 2.6. As previously analyzed, it can be observed that the left-hand circular polarization (LHCP) wave is excited by the antenna, and the cross polarization is right-hand circular polarization (RHCP). The cross polarization of the antenna is well suppressed.

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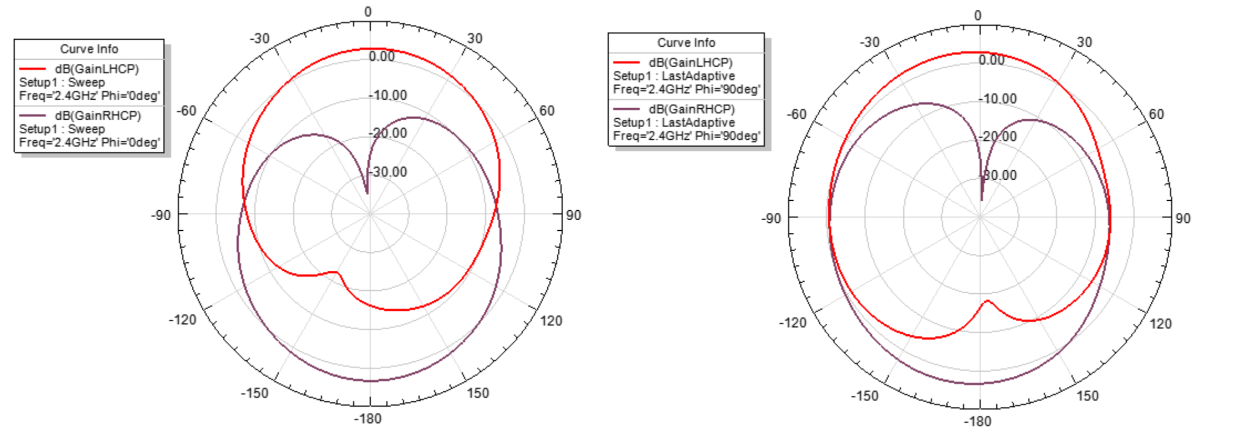
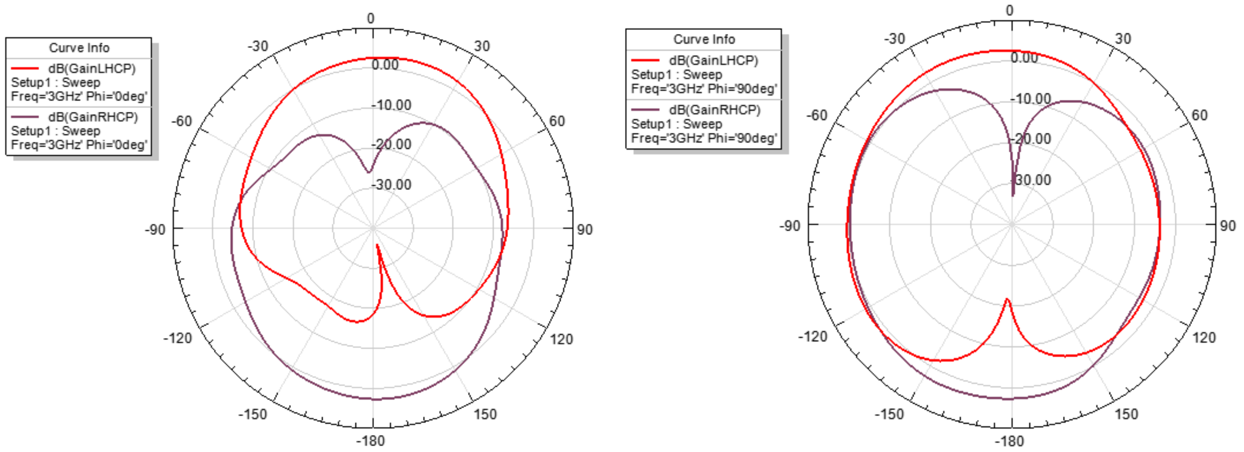


(a) 2.4GHz



(b) 3GHz

Figure 2.7. Radiation pattern of antenna at 2.4GHz and 3GHz

3. Effect of bending on antenna performance

The performance change of the antenna when it is bent determines the actual usability of a flexible antenna. Thus, it is of great significance to study the bending characteristics of such antenna.

The bending models of antenna are built in HFSS software. The longitudinal bending has been achieved by wrapping the antenna around an imaginary cylinder along the X-axis.

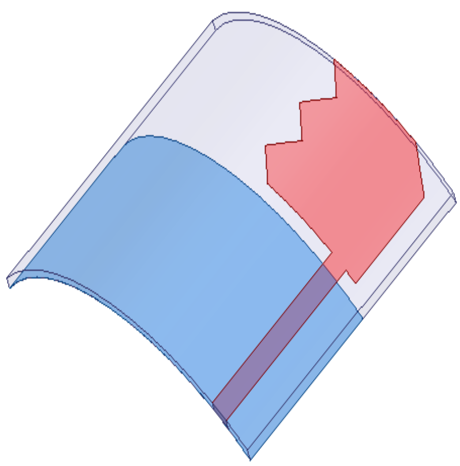


Figure 3.1. Longitudinal bent CP antenna (X-axis)

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The transversal bent antenna is wrapped around an imaginary cylinder of Y-axis.

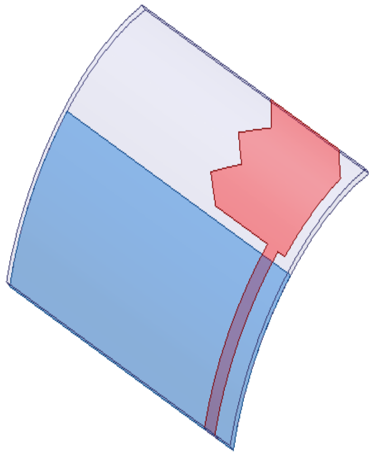
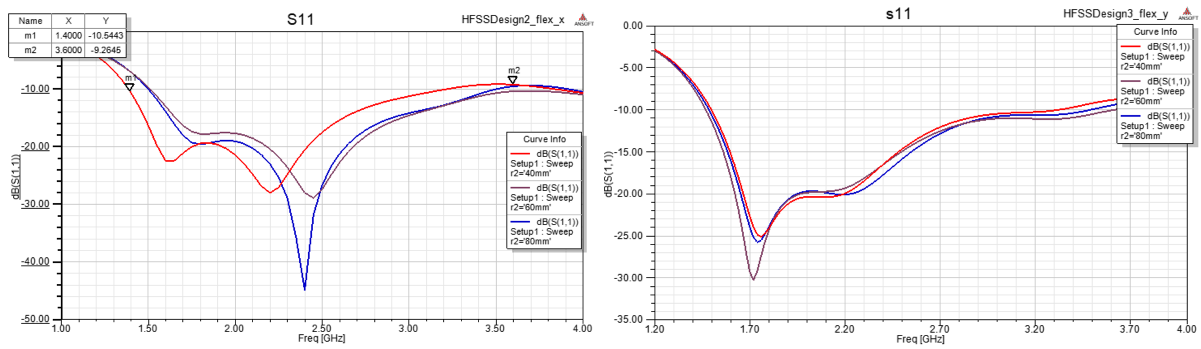


Figure 3.2. Transversal bent CP antenna (Y-axis)

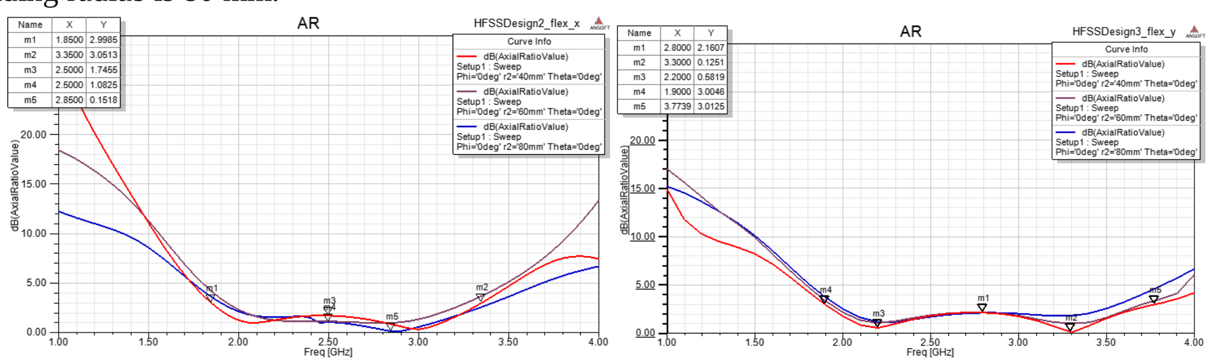
To analyze the bending characteristics of the antenna, the antenna was bent transversely and longitudinally on the cylinder with the radius of 80 mm, 60 mm and 40 mm respectively. The smaller the radius of the cylinder, the greater the deformation of the antenna. The return loss and axial ratio of the antenna with different bending radius are checked by HFSS software.



(a) Longitudinal bent (b) Transversal bent

Figure 3.3. Reflection coefficient of bent antenna

Form figure 3.3 it can be seen that longitudinal bending has more influence on the reflection coefficient of the antenna. With the decrease of the bending radius of the antenna, the resonance frequency of the antenna shifts to high or low. This may be because the electric length of the antenna changes when it is bent. Surprisingly, the reflection coefficient of the antenna is the lowest when the bending radius is 80 mm.



(a) Longitudinal bent (b) Transversal bent

Figure 3.4. Axial ratio of bent antenna

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From the simulation results in figure 3.4, compared with the return loss, the influence of antenna bending on the axial ratio is smaller. Different degree of bending makes the amplitude of the axial ratio of different frequencies change, but the curve of the axial ratio does not deviate greatly.

4. Conclusion

A broadband circular polarized flexible antenna is proposed in this paper, EGaIn liquid metal is used as the ground and radiator of the antenna, and PDMS is used as the substrate. The simulation results show that the impedance bandwidth of the antenna is 80.4% (1.45 GHz to 3.4 GHz), and the 3dB axial ratio bandwidth is 71% (1.76 GHz to 3.7 GHz). The bending models of antenna are built and their performance is analyzed. The results show that the antenna can be a candidate for a variety of broadband flexible electronic systems.

References

[1] Balanis, C. A. Antenna theory: a review. Proceedings of the IEEE, 1992,80(1), 7–23.

[2] Constantine A. Balanis. Modern antenna handbook, Hoboken, NJ: Wiley, 2008.

[3] Ramesh. Garg, Prakash.Blartia, Inder. Bahl, Apjsak. Ittipiboon, Microstrip Antennas Design Handbook, Atrech House, 2001, 2-3.

[4] Du, B., and Yung, E. A single-feed TM21-mode circular patch antenna with circular polarization, Microwave Optics Technology Letters, 2002, 33(3), 154–156.

[5] Licul, S., Petros, A., and Zafar, I., “Reviewing SDARS antenna requirements,” Microwaves & RF ,2003, 43, 51–62

[6] Dickey, M. D, Chiechi, R. C., Larsen, R. J., Weiss, E. A., Weitz, D. A., & Whitesides, G. M. Eutectic Gallium-Indium (EGaIn): A Liquid Metal Alloy for the Formation of Stable Structures in Microchannels at Room Temperature. Advanced Functional Materials, 2008, 18(7), 1097–1104.

[7] Hayes G J, So J H , Qusba A , et al. Flexible Liquid Metal Alloy (EGaIn) Microstrip Patch Antenna. IEEE Transactions on Antennas and Propagation, 2012, 60(5):2151-2156.

[8] Hamouda Z, Wojkiewicz J L , Pud A A , et al. Dual-Band Elliptical Planar Conductive Polymer Antenna Printed on a Flexible Substrate. IEEE Transactions on Antennas & Propagation, 2015, 63(12):5864-5867.

[9] Alqadami A S M, Jamlos M F . Design and Development of a Flexible and Elastic UWB Wearable Antenna on PDMS Substrate. The 2014 IEEE Asia-Pacific Conference on Applied Electromagnetics. IEEE, 2014.

[10] Angel, Bolanos-Torres, Miguel. Multiband Flexible Antenna for Wearable Personal Communications. Wireless Personal Communications, 2018.