Circular Polarization Spiral Antenna Design for NLJD Application

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Abstract

This paper presents a design of spiral antenna with broad bandwidth for non-linear junction detector (NLJD). In order to realize high directivity and high gain of the proposed antenna, the cavity wall and metal cap were considered in design.

Keywords : Spiral antenna, Circular polarization, Non-linear junction detector(NLJD)

1. Introduction

Recently, the illegal usage of minimized electronic device has been issued by super minimal electronic product technology development. These devices are frequently used for the illegal propose such as hidden wiretapping, camera, bomb and threat of terror. Many countries including the United States have been developed steadily Non-Linear Junction Detector (NLJD) which searches the hidden small device such as semi-conductor without metal for solving this problem. The NLJD system performances are determined by an antenna gain. High quality NLJD must be long detecting range to search the hidden device.

In order to minimize the effect of power reduction by reflected polarization wave from the hidden device, circular polarization antenna is mainly used for NLJD application [1]. Antenna bandwidth is separated by transmitting frequency and receiving frequency**.** Therefore, antenna must operate in a broad bandwidth. Spiral antenna has been studied a good candidate as NLJD antenna [2][3]. Therefore, a design of spiral antenna with broad bandwidth for NLJD application is presented in this paper.

2. Antenna theory and design

Fig. 1 shows the characteristics of harmonic frequency reflected by various devices. The NLJD can search small device which has different response for harmonic frequency according to the composed materials. As shown in Fig. 1, semi-conductor and false junction with different materials are responded at 2^{nd} and 3^{rd} harmonic frequency, respectively. The required antenna bandwidth of Tx and Rx frequency are from 0.8 to 1 GHz and from 1.6 to 3 GHz, respectively.

Fig. 2 shows an example of a spiral antenna's arm pattern [4]. To realize the impedance matching and penetration of electromagnetic wave, the substrate of antenna used the teflon dielectric material having low permittivity. Antenna size is determined by eq. (1). Where, C is the speed of light.

$$r_{in} \le \frac{c}{2\pi f_{high}}, \quad r_{out} \ge \frac{c}{2\pi f_{low}} \tag{1}$$

r_{out} means the distance from the center of spiral antenna to edge. Antenna diameter is set by a 150 mmφ. The radiation plane was designed by having 4-turn spiral line. The designed spiral line width and line gap were 0.6 mm and 17 mm, respectively.

Fig. 3 shows structure of spiral antenna with and without slit ground plane to study impedance matching effect of ground plane.

Fig.4 shows the calculated return loss of spiral antenna by the ground structure. To realize the broadband antenna with multi-resonance, ground plane with slit to keep the same current distribution between radiating plane and ground plane is considered by the spiral structure. In case of the without the spiral slit on ground plane, the antenna wasn't resonant due to miss matching of impedance by current distribution between radiating plane and ground plane. The spiral slit width of ground plane was designed by 1 mm, and the slit width was fixed 8 mm. Spiral line turning number on radiating plane and ground plane is same with 4-turn. Even though multi-resonance was generated by with spiral slit, it was not satisfied to broad bandwidth. To solve this problem, a patch located on radiating plane as radiating element for impedance matching was proposed and designed.

Fig. 5 shows structure of radiation element placed on center position of spiral antenna. An elliptical patch as radiating element located on center position of radiating surface was designed for broad bandwidth of spiral antenna. This patch also operated as impedance matching element between radiating plane and ground plane. Fig. 6 shows the calculated S_{11} characteristics of spiral antenna with and without radiation element. As mentioned at the explanation of Fig. 5, the return loss of spiral antenna with patch was remarkably improved by comparison of antenna without patch.

Fig 7 shows the designed configuration of the proposed antenna with cavity wall and metal cap considering NLJD system. Metal cap was placed at just up layer of the ground plane. In order to realize high gain of the proposed antenna, the cavity wall made of Fr4-epoxy and metal cap were considered in design.

Fig. 8 shows the calculated return loss of antenna with and without metal cap. It was improved about 4 dB with comparison of antenna without metal cap.

Fig. 9 shows the calculated radiation pattern of antenna with and without metal cap and cavity wall. The calculated pattern of antenna without metal cap and cavity wall appeared omni-direction, while one of antenna with cap and cavity wall had circular directivity as shown in Fig. 9.

3. Measurement

In order to verify the propriety of designed antenna, it was fabricated and measured as shown in Fig. 10. Fig. 11 shows the comparison of result between simulated and measured return loss. The fabricated antenna was satisfied with the transmission frequency band from 0.8 to 1 GHz and the receive frequency band from 1.6 to 3 GHz, respectively. The simulated and measured return loss agrees well with each other. Fig. 12 shows measured radiation patterns at center frequency of the interested band. The circular polarization characteristic at the design frequency band observed and it was reasonable agreement with the simulation result as shown in Fig. 9.

4. Conclusion

This paper described broadband spiral antenna with circular polarization for NLJD system. The measured main beam directivity toward –z axis direction agreed well with calculation result. The measured axial ratio satisfied the circular polarization within –z axis ±45° at design frequency bands and showed reasonable agreement with prediction.

5. Figures and Tables

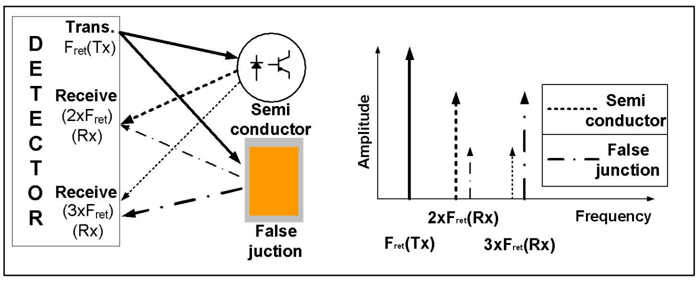


Figure 1: Characteristics of harmonic frequency reflected by various devices.

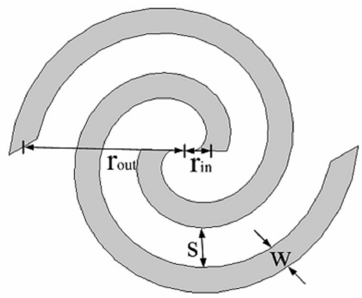
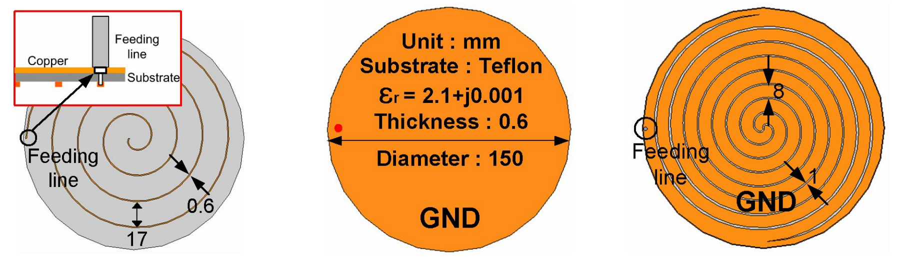


Figure 2: An arm pattern of spiral antenna.



(a) Radiating plane (b) ground without spiral slit (c) ground with spiral slit

Figure 3: Structure of spiral antenna with and without slit ground.

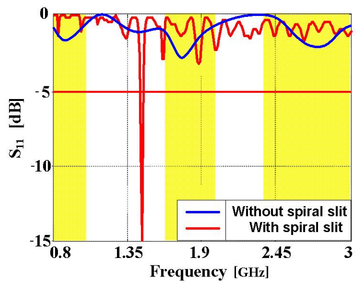


Figure 4: Calculated S_{11} characteristics of spiral antenna with and without spiral slit ground.

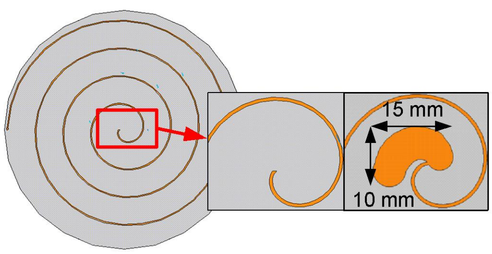


Figure 5: Design structure of radiation element placed on center position of spiral antenna.

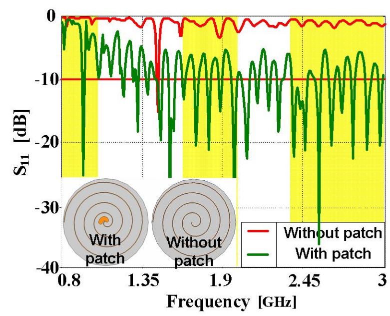
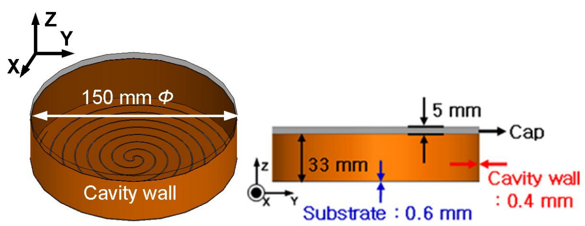


Figure 6: Calculated S_{11} characteristics of spiral antenna with and without radiation element.



(a) Perspective view (b) Side view

Figure 7: Configuration of the proposed antenna.

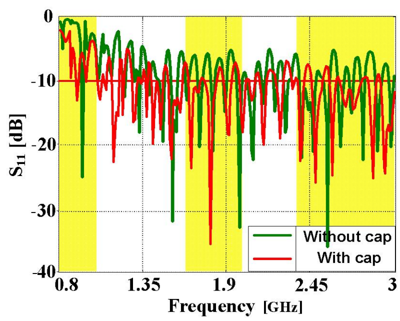


Figure 8: Comparison of return loss by using cap.

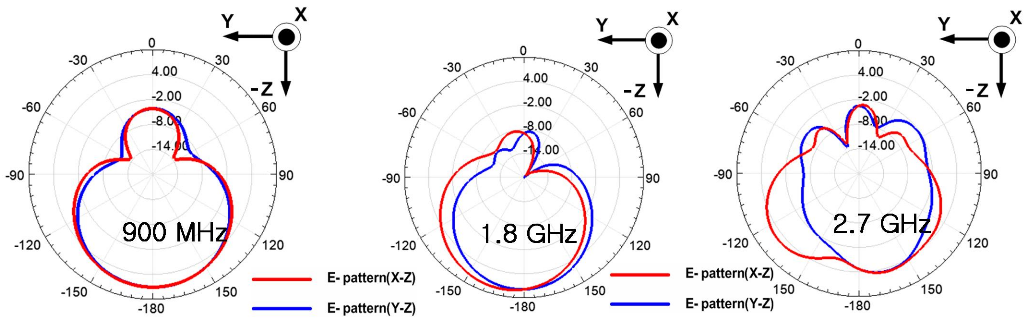


Figure 9: Calculated radiation pattern of spiral antenna with cavity wall and metal cap.

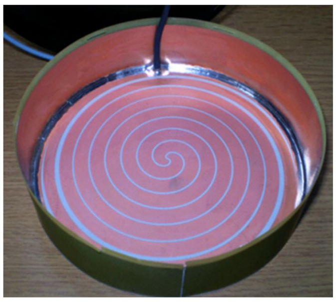


Figure 10: Photograph of a fabricated antenna.

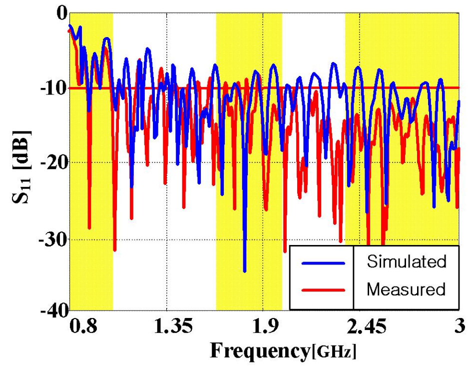


Fig. 11: Comparison of the simulated and measured return loss.

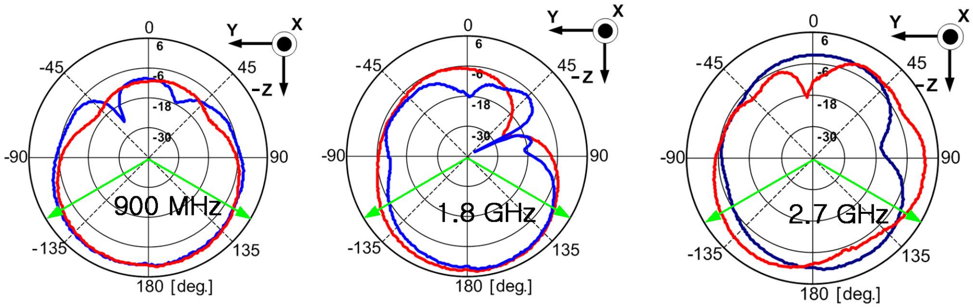


Fig. 12: Measured radiation pattern.

References

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Acknowledgments

This research was supported by the Post Brain Korea 21 and/or 2nd stage project supported by Dual Use Technology Program of Korea government.