Triple Band Spiral Antenna for Non-Linear Junction Detector

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1. Introduction

According to super minimal electronic product technology development, the illegal usage and theft from domestic of minimized electronic device such as semi-conductor, USB memory chip and etc., has been issued. These devices are frequently used for the illegal purpose such as hidden wiretapping, hidden camera, bomb and threat of terror [1]. Many countries including the United States have been developed steadily Non-Linear Junction Detector (NLJD) system which searches the hidden small device such as semi-conductor without metal and with oxidized metal for solving this problem. The NLJD system performances are mainly determined by an antenna gain and power, even though various functions of the NLJD devices exist to realize high performance. In order to minimize the effect of power reduction by coupled wave from the hidden device, circular polarization (CP) antenna has been mainly used for NLJD system application [2], [3]. In this paper, authors designed the spiral antenna with archimedean slit ground structure to realize the circular polarization. The gain of spiral antenna proposed by reference [2] had been decreased due to multi resonance characteristics. In order to solve an above problem, authors has proposed triple band spiral antenna that it is improved antenna gain, axial ratio and return loss by the optimum spiral turning number design. A proposed antenna has small size and a few turning number with comparison of reference [2]. Narrow bandwidth problem at interested band of reference [2] has been also solved by the optimized feeding position design.

2. Antenna design

Fig. 1 shows the characteristics of harmonic frequency responded by various devices. The NLJD system can detect and search the small hidden device which has different physical frequency response according to the mixed composition of different materials. False junction means an impure semi-conductor with oxidized metal. As shown in Fig. 1, a pure semi-conductor and false junction, that is to say, the impure semi-conductor with oxidized metal are responded at 2^{nd} and 3^{rd} harmonic frequency, respectively. Harmonic power level generated by a received signal is decided by a kind of the hidden device which has non-linear characteristics of the pure and the impure semi-conductor. Therefore, these phenomena have been used for searching the hidden device in NLJD system. This special electric response is able to calculate the current-voltage equation of the semi-conductor as shown in eq. (1) [4]. A kind of the hidden device is found and exposed by different amplitude level appeared at 2^{nd} and 3^{rd} harmonic frequency. These harmonic phenomena can be explained the non-linear characteristics calculated by current-voltage equation as shown in eq. (1). For example, the characteristic of semi-conductor is explained by applying the Taylor's series and the Fourier transform in eq. (1). The 2^{nd} harmonic amplitude is greater than the 3^{rd} harmonic amplitude. This is unique response characteristic of semi-conductor as shown in Fig. 1 (b). On the other hand, the characteristic of false junction is able to explain by operating of forward and/or reverse bias with respect to eq. (1). Unique response characteristic of false junction is that the 3^{rd} harmonic amplitude is greater than the 2^{nd} harmonic amplitude as shown in Fig. 1 (b). Semi-conductor and false junction used as the hidden device can be detected by their unique response characteristics.

$$I(V) = I_s\,(e^{\frac{qV}{kT}} - 1) \quad (1)$$

q : electron charge, k : Boltzman's constant, T : electron charge, I_s : saturation current

Fig. 2 shows the structure of spiral antenna. Spiral antenna size is 80 mmø, ground plane has archimedean slit structure. The teflon dielectric substrate with relative permittivity of 2.1 + j0.001 and height of 0.6 mm is considered in design. 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.

From ① to ③ of Fig. 3 show the shape of various matching elements located on radiating plane. An elliptical patch as matching element located on center position of radiating plane has been designed for broad bandwidth of spiral antenna.

Fig. 4 shows the simulated return loss characteristics without (①) and with (② and ③) various matching elements. The required antenna bandwidth of Tx and Rx frequency are from 2.4 to 2.48 GHz and from 4.84 to 4.92 GHz, and 7.28 to 7.36 GHz, respectively. Return loss characteristics are improved when shape of the matching element is ③. Because impedance depends on the shape of matching element, return loss is affected by the shape of matching element.

Fig.5 shows two kinds of (a) 4-turn and (b) 1.25-turn number for spiral structure on radiating plane. Because number of spiral turns is very important parameter for bandwidth control, it is necessary for searching the optimum spiral turning number.

Fig. 6 (a) and (b) show the simulated return loss and the simulated axial ratio by number of spiral turns. Bandwidth of spiral structure with 1.25-turn is more wide than with 4-turn, because multi resonance depends on the number of spiral turns [5]. When theta and phi equal to 0° simultaneously, an axial ratio as shown in Fig. 6 (b) is simulated in the main beam direction. When spiral turning number is 1.25-turn, axial ratio has been showed 3 dB below at interesting band.

Fig. 7 shows the simulated radiation patterns of LHCP and RHCP for 1.25-turn. The XPD (cross polarization discrimination) is about 20 dB, 15 dB and 20 dB at 2.44 GHz, 4.88 GHz, and 7.32 GHz, respectively, where theta = 0° and phi = 0°. Therefore, the good axial ratio with 3 dB below as shown in Fig. 6 (b) is shown in interested bands.

3. Measurement

In order to verify the propriety of designed antenna, the proposed antenna was fabricated as shown in Fig. 8.

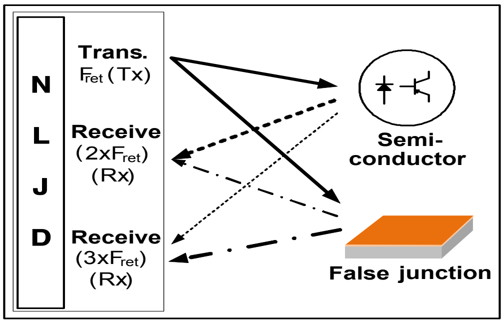
Fig.9 shows the comparison of the simulated and measured return loss. Measured return loss is slightly shifted. The cause of the frequency shift seems to be due to fabrication errors. However, two results show reasonable agreement.

Fig. 10 shows the comparison of the 2D radiation patterns simulated and measured at the design frequency. Red line and blue line indicate the simulated main polarization of E-field in the x-z direction and in the y-z direction, respectively. Dotted green line and yellow line are measured E-field pattern, and these are corresponded to solid red and blue line. Measured E-field radiation pattern showed reasonable agreement with the simulation result as shown in Fig. 10.

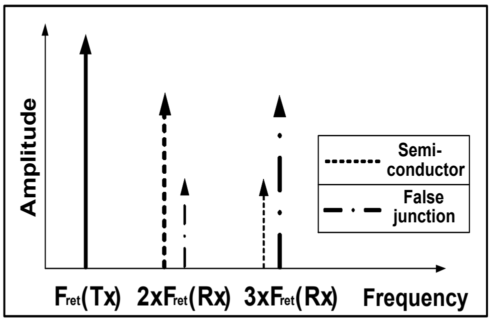
4. Conclusion

This paper describes circularly polarized triple band spiral antenna for NLJD system. Triple band is realized by decrease of turn number. Narrow bandwidth problem due to multi resonance of reference [2] has been also solved by the control of turn number and the optimized feeding position design. The measured main beam directivity toward +z axis direction agreed well with calculation result.

5. Figures

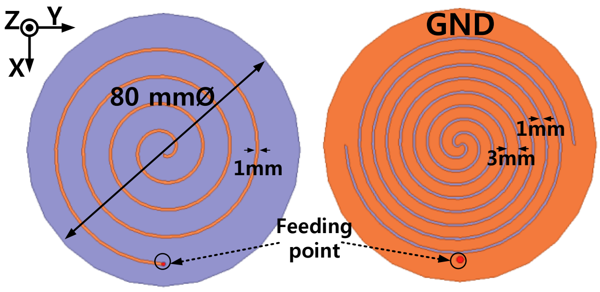


(a) The process of semi-conductor and false junction detected by NLJD



(b) The amplitude of semi-conductor and false junction by NLJD

Fig. 1 Characteristics of harmonic frequency responded by various devices [2].



(a) Radiating plane (b) Ground plane

Fig. 2. Structure of spiral antenna.

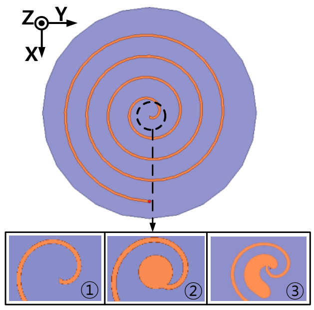


Fig. 3. The shape of various matching elements.

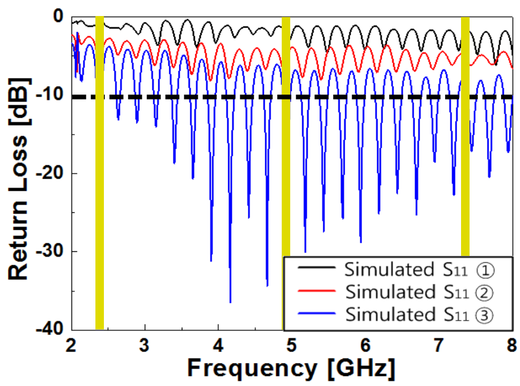
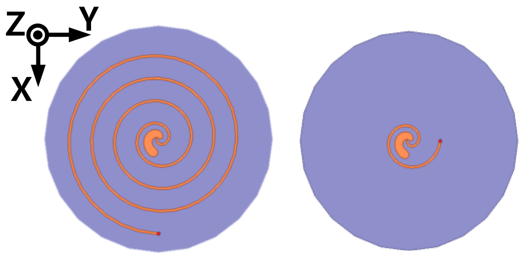
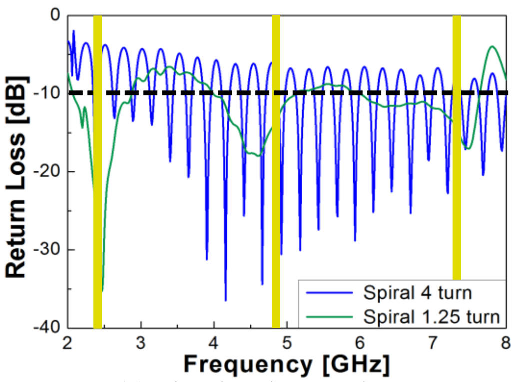


Fig. 4. Simulated return loss characteristics of various matching elements.

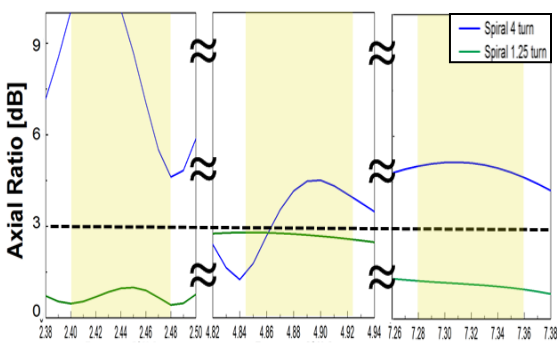


(a) 4-turn (b) 1.25-turn

Fig. 5. Various turning number of spiral.



(a) Simulated return loss



(b) Simulated axial ratio at interested bands

Fig. 6. Simulated results by number of spiral turns.

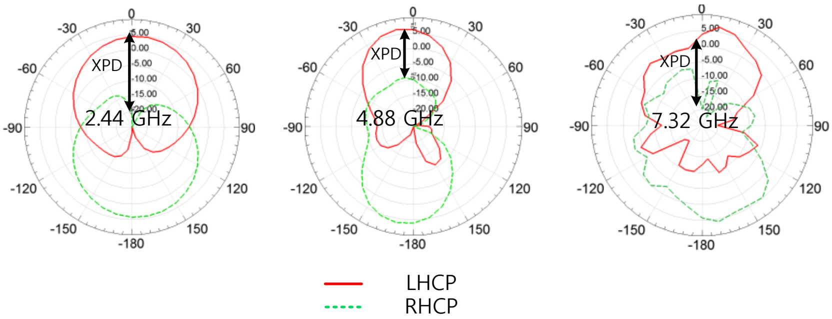


Fig. 7. Simulated radiation patterns of LHCP and RHCP for 1.25-turn.

(a) Radiating plane (b) Ground plane

Fig. 8. Photograph of a fabricated antenna.

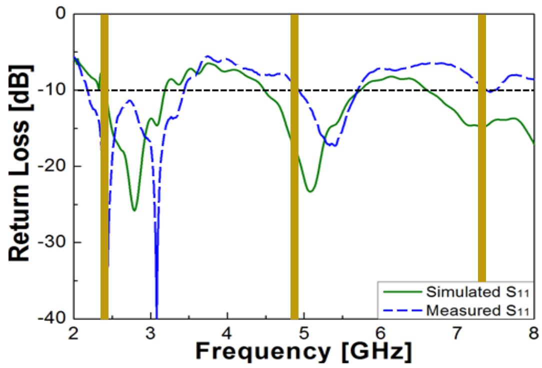


Fig. 9. Comparison of the simulated and measured return loss.

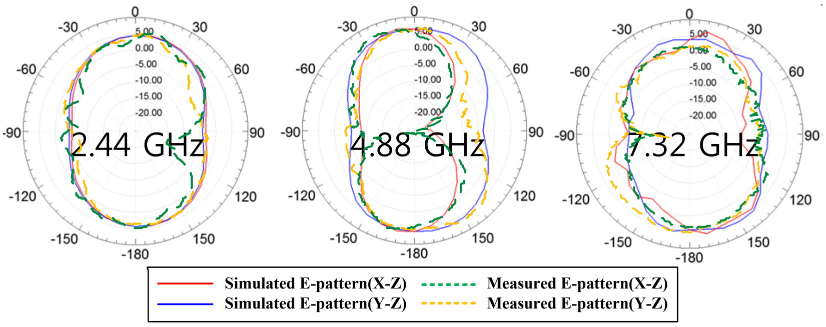


Fig. 10. Simulated and measured radiation pattern by spiral 1.25 turns.

Acknowledgments

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