Design of a Square Spiral Microstrip Patch Antenna in the 5GHz Band

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Abstract: In this paper, the characteristics of the square spiral antenna for broadband impedance bandwidth are investigated in the 5GHz band. The design is based on the 1.25-turn square spiral antenna in a finite-sized ground with coaxial SMA feeding. Likewise, the corner is truncated to allow smooth current flow. As a result, sufficient impedance bandwidth is obtained (VSWR<1.5). The modified 1.25-turn square spiral microstrip patch antenna is able to achieve an impedance bandwidth of about 920MHz or 16.2% given a VSWR of less than 1.5. Radiation patterns are broad across the pass band, with gain measuring 2.8dBi~7.3dBi.

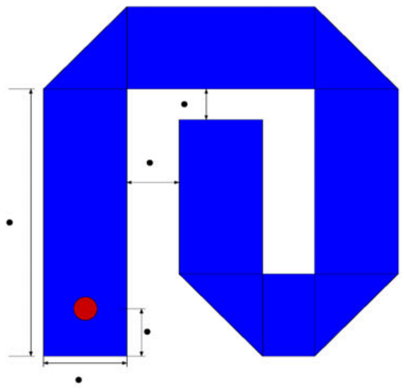
I. Introduction

In recent years, the existing frequency band is not spared from the saturation phenomenon because of the rapid increase in the demand for wireless telecommunication. Nonetheless, international discussions for the introduction of a new frequency band to overcome this problem are progressing•• Movable and immovable antennas for the 5GHz band (little output power level for indoor application in case of 5.15-5.25GHz and maximum of 1W output power level for outdoor application in case of 5.25-5.35GHz, 5.470-5.725GHz) were distributed at WRC-2003. Thus, an application and a researchable development of system are required. The result of the conference also calls for the conduct of research on compact broadband antennas for the 5GHz band.

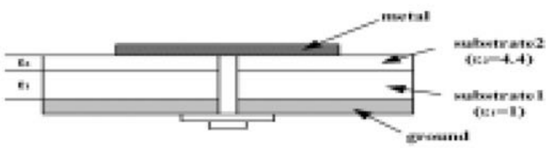
The square spiral antenna is introduced• to meet such requirement. In 1993, a square spiral antenna was compared with one having an Archimedean design and a similar size [1]. The performance characteristics of the two designs are found to be nearly identical. In practice, however, the square spiral may be advantageous compared with a circular Archimedean in terms of simplicity of construction and more efficient utilization of a limited area for a mounting plane [2]. More importantly, the square spiral antenna has wide impedance bandwidth. The enhancement of impedance bandwidth in conventional patch antennas is a result of mutual coupling between the radiators, thereby reducing the overall impedance variation at the input of the antenna [3].

In this paper, a 1.25-turn square spiral microstrip antenna is proposed for broadband impedance bandwidth in the 5GHz band. The corner is truncated to obtain higher gain and broadband radiation pattern in proportion to conventional spiral antenna allowing smooth current flow. Experimental results for the broadband impedance bandwidth, radiation pattern, and gain are displayed.

II. Antenna Design



(a) top view of the proposed square spiral antenna



(b) side view of the proposed square spiral antenna

Figure 1. Configuration of the square spiral antenna. (a) top view of the proposed square spiral antenna; (b) side view of the proposed square spiral antenna.

Figure 1 illustrates the antenna geometry of the modified square spiral microstrip patch antenna. A prototype design is done using Ensemble 5.0 from Ansoft, Inc., based on the method of moment in frequency domain. The antenna is designed to work in the 5GHz frequency band, with VSWR of 1.5:1 over the designated frequency range. Occupying an area of 17×17 mm ^{2}, the corner is truncated to allow smooth current flow. The radiating patch is printed on a thin FR-4 substrate with thickness of 1.6mm and relative

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permittivity of 4.4. The ground plane has a size of 30 × 30 mm ^{2}. The width of the patch, the distance (X and Y) of the patch, the thickness of the airgap, and the position of the feeding point are changed in steps, with the bandwidth calculated at each step obtained and optimized until a good return loss characteristic is achieved for the 5GHz band.

II.1 Width of W

Figure 2 shows the simulation results of W. Based on the variation of W from 3.0mm to 5.0mm, the characteristic of return loss is analyzed (Figure 2). An increase in W is observed to cause the higher resonance frequency of the proposed antenna to shift to the lower frequencies. As a result, the distance between the lower and higher resonance frequencies narrows further. The best characteristic of return loss is obtained at W=4.0mm.

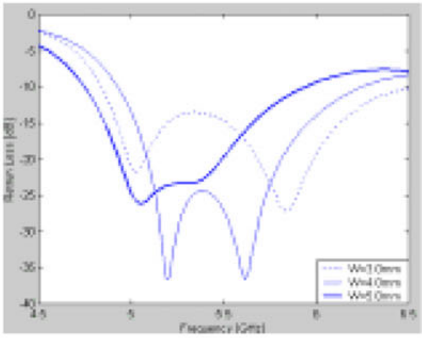


Figure 2. Influence of the width of W on the return loss of the proposed antenna.

II.2 Position of F

Figure 3 shows the simulation results of F. Based on the variation of F from 2.3mm to 2.7mm, the characteristic of return loss is analyzed (Figure 3). An increase in F is observed to cause the higher resonance frequency of the proposed antenna to shift to the lower frequencies and the lower resonance frequency to shift to the higher frequencies. As a result, the distance between the lower and higher resonance frequencies narrows further. The best characteristic of return loss is obtained at F=2.5mm.

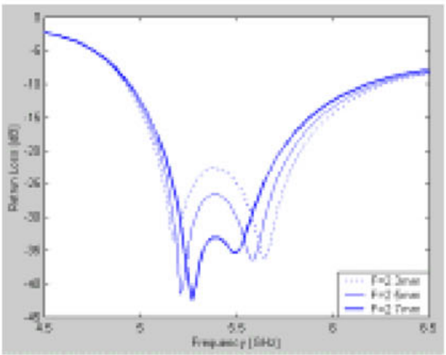


Figure 3. Influence of the width of F on the return loss of the proposed antenna.

II.3 Thickness of t_1

Figure 4 shows the simulation results of t_1. Based on the variation of t_1 from 3.5mm to 4.5mm, the characteristic of return loss is analyzed (Figure 4). An increase in t_1 is observed to cause both the lower and higher resonance frequencies of the proposed antenna to shift to the lower frequencies. The best characteristic of return loss is obtained at t_1=4.0mm.

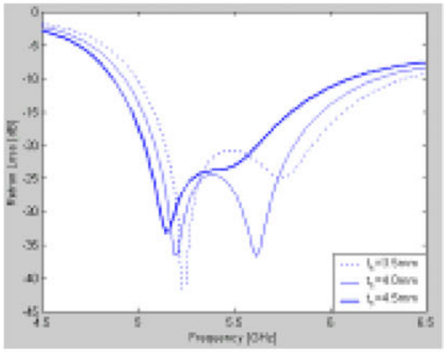


Figure 4. Influence of the width of t_1 on the return loss of the proposed antenna.

II.4 Distance of X

Figure 5 shows the simulation results of X. Based on the variation of X from 2.0mm to 3.0mm, the characteristic of return loss is analyzed (Figure 5). An increase in X is observed to cause the higher resonance frequency of the proposed antenna to shift to the higher frequencies and the lower resonance frequency to shift to the lower frequencies. The best characteristic of return loss is obtained at X=2.5mm.

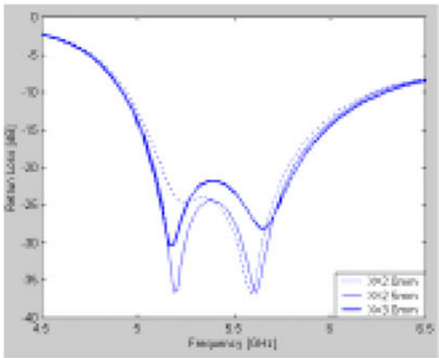


Figure 5. Influence of the width of X on the return loss of the proposed antenna.

II.5 Position of Y

Figure 6 shows the simulation results of Y. Based on the variation of Y from 1.0mm to 2.0mm, the characteristic of return loss is analyzed Figure 6. An increase in Y is observed to cause both the lower and higher resonance frequencies of the proposed antenna to shift to the lower frequencies and higher frequencies, respectively. Y=1.5mm is found to obtain a good characteristic in the Hiper-LAN band and to make fabrication easier.

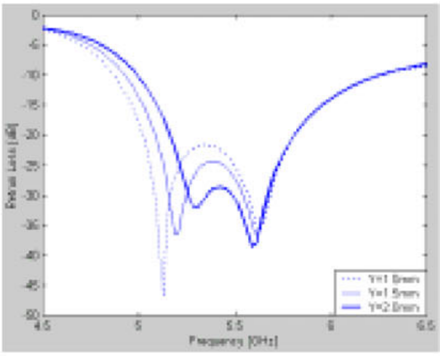


Figure 6. Influence of the width of Y on the return loss of the proposed antenna.

After a thorough parametric study of the modified 1.25-turn square spiral microstrip patch antenna, the optimum design parameters of the proposed antenna are set as follows: W=4.0mm; L=13mm; X=2.5mm; Y=1.5mm; F=2.5mm, and; t_1=4.0mm. After the optimum design is achieved, the antenna is fabricated on Du-San Cooperation's DS-7408 T/C H/H substrate with thickness of 1.6mm and $\varepsilon_r = 4.4$. Excitation of the antenna is triggered by a 50Ω coaxial SMA connector.

3. RESULTS

Based on the proposed design described earlier, this study designed, fabricated, and measured a modified square spiral microstrip antenna in the 5GHz band. The return loss of the antenna is measured using an HP8510 network analyzer, with the far-field patterns and gain measured inside an available compact range at the RFIC Center of Kwangwoon University. Figure 2 shows the measured return loss versus frequency for the proposed antenna at the starting point of 4.5GHz and stop point of 6.5GHz with an interval of 200MHz. The impedance bandwidth (1.5:1 VSWR) of the proposed antenna reaches approximately 920MHz (5.23-6.15GHz) or about 16.2%.

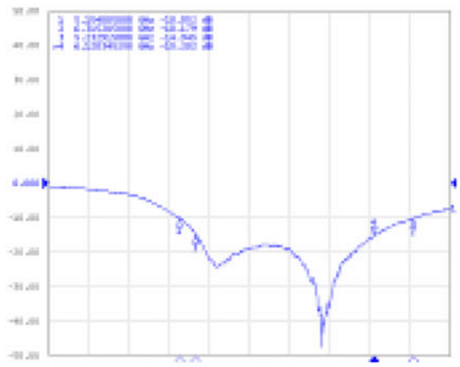
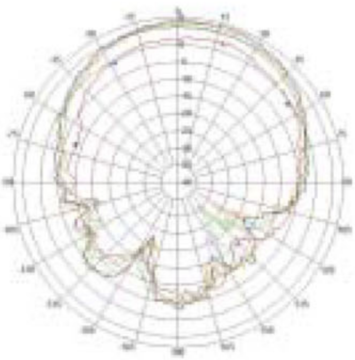
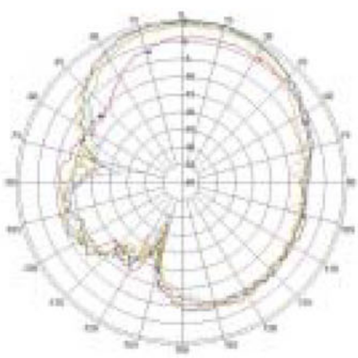


Figure 2. Measured return loss vs. frequency for the proposed antenna.

The radiation characteristics of the proposed antenna are also studied. Figure 3 shows the measured radiation patterns of the proposed antenna at 5.1, 5.3, 5.5, 5.7, and 5.9GHz. Good broadband radiation patterns are obtained. Slight asymmetry in the radiation patterns is also observed, which is largely due to the fringe and coupling effects.



(a) azimuth



(b) elevation

Figure 3. Radiation patterns of the proposed antenna at varying frequencies in the operating band. (a) azimuth; (b) elevation.

Figure 4 shows the measured antenna gain versus frequency for the proposed antenna for five frequencies across the 5GHz band. Gain is measured at 2.8-7.3dBi. The antenna gain has a peak value of 7.3dBi, with gain variations at 6.1dBi.

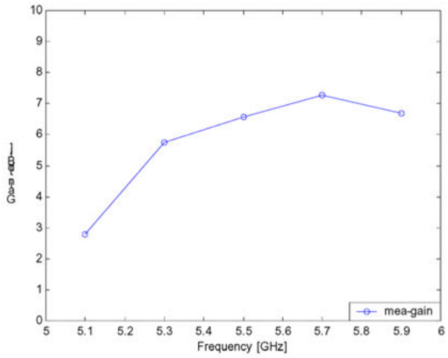


Figure 4. Measured antenna gain for operating frequencies across the 5GHz band.

IV. CONCLUSION

A modified 1.25-turn square spiral microstrip antenna is proposed, described, and experimentally investigated for broadband impedance bandwidth. By varying the width of the patch, the gap (X and Y) of the patch, the thickness of the foam, and the position of the feeding point, optimizing parameters are obtained to determine the good characteristic of the return loss for the operating band. The obtained impedance bandwidth (1.5:1 VSWR) covers 920MHz or 16.2%. The proposed antenna also shows good broadside radiation characteristics at the measured frequency. Gain is measured at 2.8-7.3dBi. Therefore, the antenna is suitable for practical applications requiring small and broadband antennas in the 5GHz (HerperLan 1/2, ISM) band.

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