TWO-ARM MICROSTRIP SPIRAL ANTENNA FOR MULTI-PATTERN CONTROL

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1. Introduction

The spiral antenna shows characteristics of frequency independence where radiation pattern, impedance, and polarization are not changed appreciably over a wide range of frequency. Additionally, spiral antennas maintain the advantage of being able to attain various radiation patterns according to the number of spiral arms and feeding techniques. For such radiation characteristics, spiral antenna has been used in many fields and has found such broad application as direction finding systems, military surveillance systems, and commercial communication systems.

It has been known that the number of useful radiation modes that can be attained with a conventional N-arm spiral antenna is N-1, because the conventional spiral antenna is fed from the central part of spiral generates radiation from the feedline when all spiral arms are fed in-phase [1]. Therefore, it is difficult to attain a second mode pattern with a conventional two-arm spiral antenna. However, a two-arm microstrip spiral antenna that is composed of the external feeding structure using the inward traveling wave [2-5] yields a very little interference between the two separated feedlines positioned oppositely. This characteristic allows the two spiral arms of the antenna to be fed a variety of phase differences.

In this paper, we propose an antenna that can control four different beam types using a two-arm spiral line. Various beam patterns can be achieved according to spiral mode, which is altered by controlling the phase difference between two feedlines that are connected to the outer end of the spiral through the phase shifter. This antenna has an advantage of increasing efficiency of transmitting and receiving in a rapidly changing electromagnetic communication environment, as it can radiate various beam patterns selectively.

2. Antenna geometry and characteristics

Fig. 1 shows photographs of the proposed two-arm microstrip spiral antenna with switched beam capability. A circular aperture with a radius of r_o is located on the ground plane, and a guard ring is placed at the outer edge of the circular ground plane for the purpose of improving axial ratio. Spiral radiators, phase shifters, and feedlines are located on the other side of the substrate. Two spiral arms are of the Archimedean spiral type, and one of the spiral arms is represented as

$$r(\varphi) = a\varphi + r_a\,, \quad (\varphi_s \le \varphi \le \varphi_e) \qquad (1)$$

Here, $r(\varphi)$ is the radial distance from the origin to the arbitrary point on the centerline of the spiral, a is the spiral constant, φ is the winding angle, and r_a is the radial distance from the origin to the initial point of the spiral line. The second spiral arm is situated at a 180° rotation from the first spiral arm relative to the origin. A 50 Ω microstrip line is divided into two 100 Ω microstrip lines that feed the spiral antenna through the phase shifter from the outer end of the spiral arms. The phase shifter is composed of two lines, and a series diode switched line type switching circuit [6] was realized by

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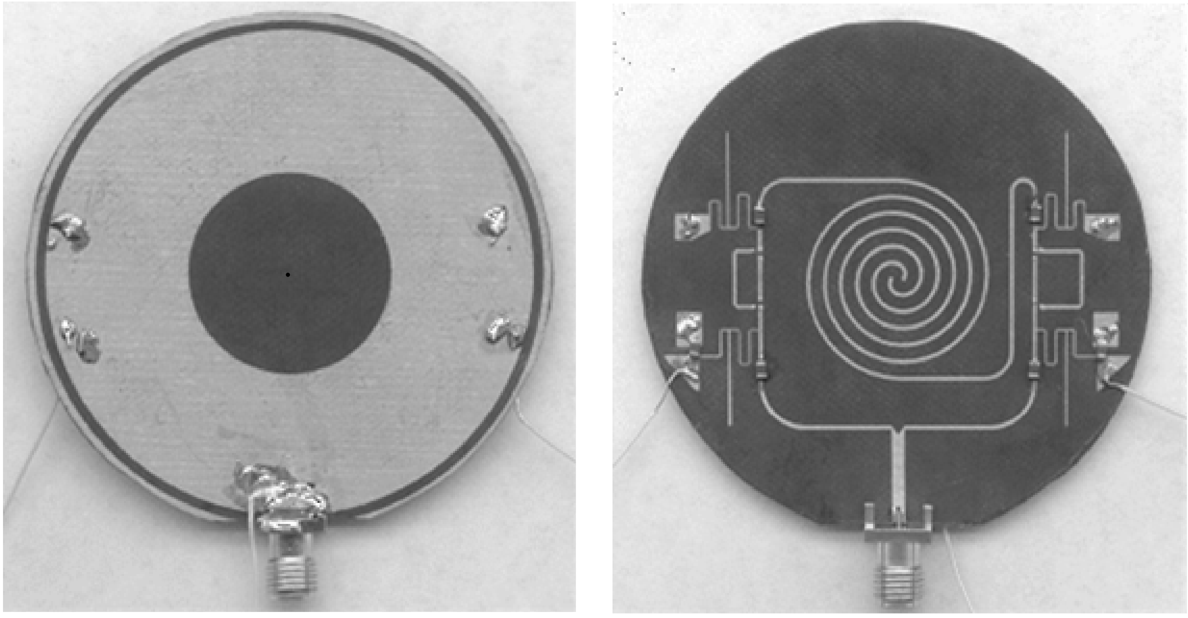
Table 1. Beam characteristics for 4 different phase shift cases

	Phase difference	Beam type	Measured Gain
Case 1	180°	Normal beam	1.3 dBi
Case 2	360°	Conical beam	– 1.0 dBi
Case 3	+ 90°	Tilted beam	0.3 dBi
Case 4	– 90°	Tilted beam	0.1 dBi

using two HPND 4028 PIN diodes [7] at each line. A total of 4 pin diodes was used in each phase shifter. Phase shifters are operated by DC bias of ± 1.6 V, and they are designed to feed the spiral antenna with four phase differences; 360°, 180°, 90°, and – 90°.

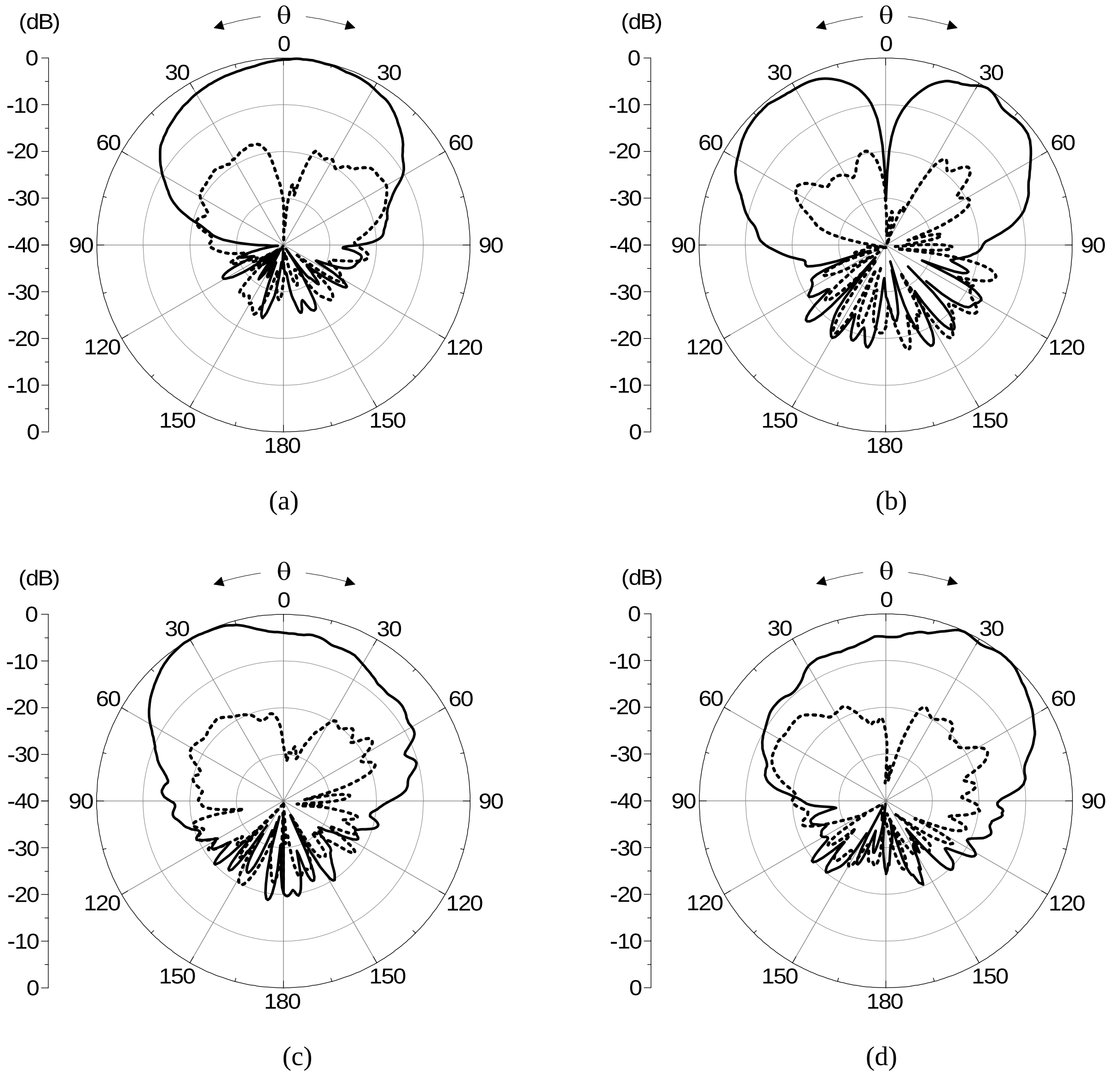
The antenna was fabricated on a substrate with a dielectric constant of 2.2 and a thickness of 0.508 mm (RT Duroid 5880). Since this antenna has a circular aperture, it radiates to both sides of the antenna. In order to attain unidirectional radiation, a conductor backed 19 mm thick AN-74 electromagnetic wave absorber manufactured by Emerson & Cuming is placed, along with a 10 mm styrofoam spacer, under the backside of the antenna. The design parameters of the antenna are: the radius of the circular ground plane = 28 mm, the radius of the circular aperture = 11.5 mm, the width of the 50 Ω microstrip line = 1.55 mm, the width of the spiral arm and the 100 Ω microstrip line = 0.45 mm, the spiral constant (a) = 0.61275 mm/rad, the radial distance from the origin to the initial point of the spiral line (r_a) = 0.75 mm, the spiral start angle (φ_s) = 0 rad, and the spiral end angle (φ_e)=17.6 rad. The polarization sense of the spiral is the same as that of the spiral winding direction from the outer to the inner arm as seen from the side of the circular aperture. For this antenna structure, right-hand circularly polarized (RHCP) waves radiate to the upper half of the plane.



(a) (b)

Fig. 1. The proposed two-arm microstrip spiral antenna structure; (a) front side, (b) back side.

Table 1 shows beam characteristics of the spiral antenna under 4 different cases of phase shift, and Fig. 2 shows their measured radiation patterns at 10.5 GHz, with an axial ratio lower than 3 dB being met for all measured cases. The phase-amplitude method [8] was used to measure radiation patterns. Case 1 shows a radiation pattern with out-of-phase feed (180° phase difference between the two feedlines) and exhibits a normal beam pattern that corresponds to the first mode of the spiral antenna. Case 2 shows a radiation pattern with in-phase feed (360° phase difference between the two feedlines: we used a phase difference of 360° instead of 0° to ease phase shifter design) and exhibits a conical beam pattern that corresponds to the second mode of the spiral antenna. Cases 3 and 4 display radiation patterns with phase differences of +90° and −90°, respectively, and exhibit tilted beams that maintain opposite directions with respect to the vertical axis. The measured gains for the normal beam, the conical beam, and the two tilted beams are 1.3 dBi, −1.0 dBi, 0.3 dBi, and 0.1 dBi, respectively. The gain of the antenna is about 2~3 dB lower than expected [5] due to loss in the PIN diode present at a high frequency. This problem can be improved by using low-loss RF or MEMS switches. Fig. 3 shows the measured VSWR of the spiral antenna for 4 different cases of the phase shifter. In all cases, a VSWR less than 2 is attained for the frequency range of 10.18 GHz and 11.39 GHz.



(a)

(b)

(c)

(d)

Fig. 2. Radiation pattern for 4 different phase shift cases; (a) Case 1, (b) Case 2, (c) Case 3, (d) Case 4. —— RHCP, - - - - - LHCP.

3. Conclusion

In this paper, we have proposed a two-arm microstrip spiral antenna for multi-beam pattern control. With this antenna, a normal beam, a conical beam, and two tilted beams can be obtained by using phase shifters that are designed for use at the outer end of the spiral lines. This two-arm microstrip spiral antenna can be used to increase the efficiency of transmitting and receiving by controlling the radiation pattern under rapidly changing electromagnetic environments.

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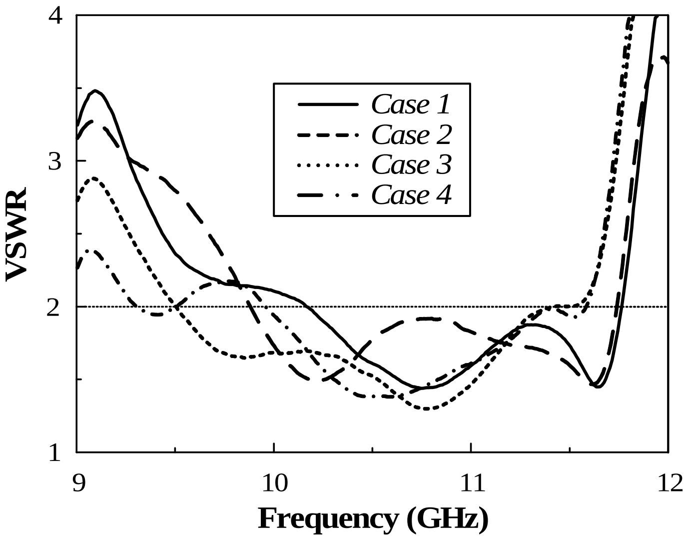

Fig. 3. VSWR for 4 different phase shift cases.