Reconfigurable Beam Steering Antenna Using Double Loops

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Abstract

A novel reconfigurable beam steering antenna composed of double loops is presented. The proposed antenna is able to steer an elevation angle of antenna beam direction by the superposed beam of double loops, and can steer an azimuth angle of antenna beam direction by using artificial switches.

Keywords : Reconfigurable antenna Beam steering Loop antenna Superposed beam

1. Introduction

The beam steering antenna with directivity to the desired direction has been investigated. The beam steering antenna has the ability to adjust its beam pattern. The beam steering antennas are mostly classified into either adaptive array antenna or single antenna element [1]. The adaptive array antenna offers better gain than single antenna element. However, the size of the adaptive array antenna is much bigger than that of single antenna element [1-2].

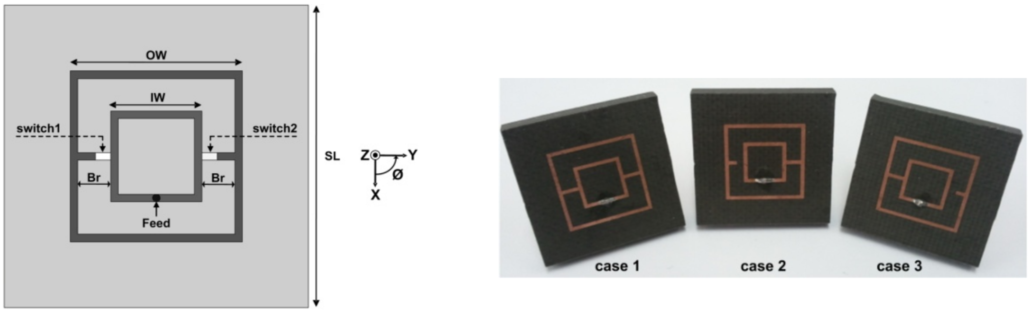
At present, the adaptive array antenna has been used as the most common type of steerable antenna. The size of the antenna has to be reduced gradually due to space limitation. Therefore, the single element antenna with beam steering capability is required for the practical implementations. Also, the research about the reconfigurable beam steering antenna by single antenna element has been researched [3-5].

In this paper, the reconfigurable beam steering antenna using double loops is proposed. The proposed antenna uses two artificial switches for variations of beam pattern. By insetting artificial switches, the beam pattern is controlled symmetrically. The tilted beam pattern is implemented by superposing the fundamental frequency at the inner loop and first harmonic frequency at the outer loop. Simulation and measurement results confirm that the steering characteristic is able to realize by using two artificial switches.

2. Antenna design and configuration

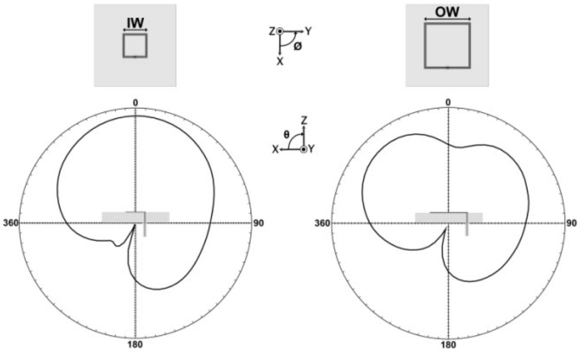
Fig. 1 shows the configuration of the proposed antenna. The antenna is fabricated on the PCB substrate. The PCB substrate uses Rogers RT/Duroid 5880 ($\varepsilon_r = 2.2$, tan $\delta = 0.0009$). The dimension of the substrate is a square (SL) of 20 mm x 20 mm, and the thickness of the substrate is 3.175 mm. The proposed antenna is fed by a coaxial probe in the bottom centre of the inner loop, and the ground is backed in the bottom plane. The antenna consists of double loops, inner loop (IL) and outer loop (OL). The width of the inner loop (IW) is 6 mm and the outer loop (OW) is 11.3 mm, where the line width of the loops is 0.5 mm. The IL and OL are able to connect or disconnect by using two artificial switches in two bridges (Br = 2.15mm). Depending on the state of switches, three cases of state can be possible (case 1, case 2, case 3). The case 1 denotes that both switch (1) and switch (2) are in ON-state. The case 2 denotes that only switch (2) is in ON-state. The case 3 denotes that only switch (1) is in ON-state as shown in Fig. 1 (b). The fabricated prototype antenna is shown in Fig. 1 (b).

Fig. 2 (a) shows the radiation pattern of the IL at the fundamental frequency, 12.8 GHz and Fig. 2 (b) shows the radiation pattern of OL at the first harmonic frequency, 12.8 GHz. Also, Fig. 3 shows that the fundamental frequency of IL and the first harmonic frequency of OL are operated at the same frequency, 12.8 GHz. The radiation pattern of the IL is in-phase beam ($\theta_{\max} = 0^{\circ}$ at $Ø = 0^{\circ}$) at the fundamental frequency, and the radiation pattern of the OL is out-phase beam ($\theta_{\max} = 320^{\circ}$ at $Ø = 0^{\circ}$) at the first harmonic frequency. The peak gain of the IL is 6.9 dBi, and the OL is 5.2 dBi. By the superposed beam of both the in-phase beam in the IL and the out-phase beam in the OL, the double loop antenna is able to steer an elevation angle of maximum beam direction. And by using artificial switches, an azimuth angle of maximum beam direction can be steered.



(a) (b)

Figure 1: The proposed reconfigurable beam steering antenna with two artificial switches.
(a) Top view of the proposed antenna, (b) Fabricated prototype antennas (case 1, 2, 3)



(a) (b)

Figure 2: Simulated radiation patterns at Φ = 0° cut.
(a) Inner loop at the fundamental frequency (12.8 GHz),
(b) Outer loop at the first harmonic frequency (12.8 GHz)

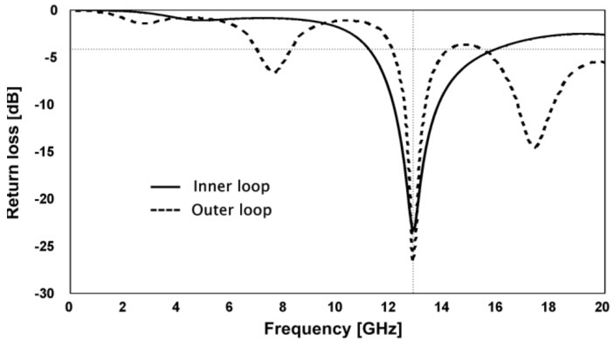


Figure 3: Simulated return losses of the inner loop and the outer loop.

3. Results and Discussion

Measured results of the return losses for three cases (case 1, case 2, case 3) are plotted in Fig. 4. The case 1 antenna and the case 3 antenna operate in 14.5GHz, the case 2 antenna operate in 14.4GHz. The return losses of all the cases 1, 2, 3 are under -10 dB. By connecting the IL and OL, the operation frequency (14.5 GHz) is slightly higher than that of two single loops (12.8 GHz) as shown in Fig. 3.

Fig. 5 shows the measured radiation patterns of three cases in the θ plane. In the case 1, the maximum beam direction is in the Z-axis of $\theta_{max} = 0°$ at Ø = 0° cut, and HPBW is 95°. In the case 2, the maximum beam direction is $\theta_{max} = 320°$ at Ø = 50° cut, and HPBW is 105°. In the case 3, the maximum beam direction is $\theta_{max} = 40°$ at Ø = 130° cut, and HPBW is 105°. The radiation pattern of the case 2 and 3 are symmetrical tilted beams from the Z-axis. The simulated 3-dimensional radiation patterns of three cases are shown in Fig. 6. The peak gains of the antenna are 5.32 dBi at the case 1, 5.83 dBi at the case 2, and 5.78 dBi at the case 3, respectively. The summarized performances (Maximum beam direction, Peak gain, HPBW) are shown in table 1.

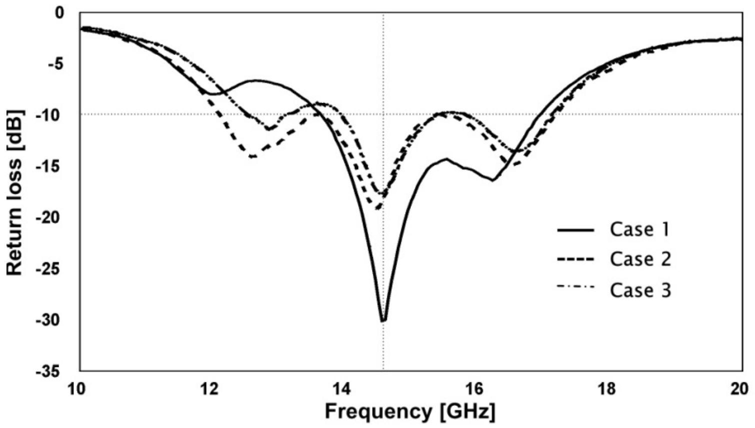


Figure 4: Measured return losses of the proposed antenna.

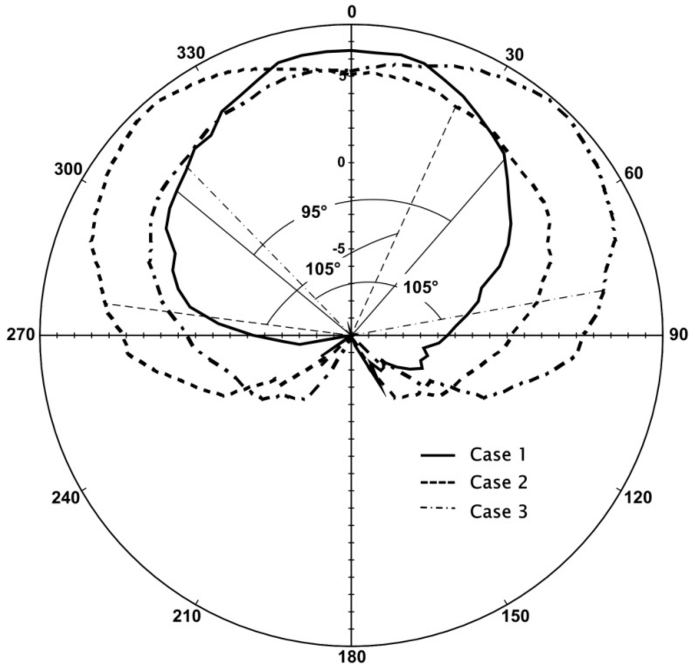


Figure 5: Measured radiation pattern of the antenna at 14.5 GHz (ϴ plane).

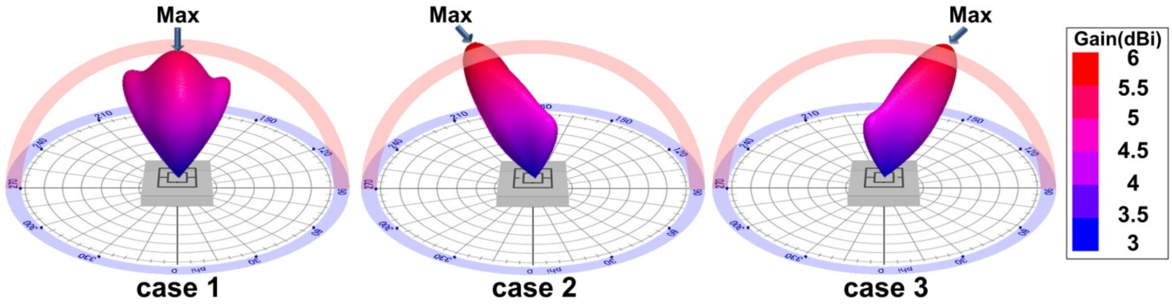


Figure 6: Simulated 3D radiation patterns of the antenna at 14.5 GHz.

4. Conclusion

In this paper, the reconfigurable beam steering antenna using double loops is designed and analyzed. The measurement results confirm that the proposed antenna with two artificial switches provides steering beam capability by the superposed beam of double loops. This method to steer the beam direction is easily able to modify at the numerous beam steering applications.

Table 1: Summary of the Maximum beam Direction, Peak gain, and HPBW

	Switch 1	Switch 2	Max. Beam Direction(°)		Peak Gain(dBi)	HPBW(°)
			Phi(Φ)	Theta(Θ)		
Case 1	On	On	0	0	5.32	95
Case 2	Off	On	230	40	5.83	105
Case 3	On	Off	130	40	5.78	105

References

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Acknowledgments

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