Reconfigurable beam steering 3D antenna for intelligent antenna system

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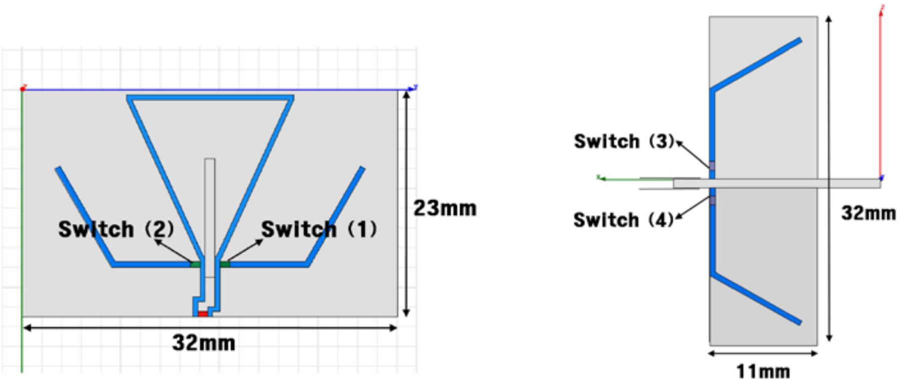
Ⅰ. Introduction

Intelligent antennas have recently received increasing interest due to the development and rapid spread of the complicated modern telecommunication services and electronic devices. Intelligent antenna design technologies include reconfigurable antenna radiation patterns, variable operating frequency ranges, and antenna isolation techniques between various antennas. Intelligent antenna systems are usually categorized as either switched-beam or adaptive-array systems. Both systems control their main antenna beam patterns in the general direction of the signal of interests with relatively large sizes and complicated control systems [1]. Also, the intelligent antenna systems are focusing on effective usages of the spatial dimension of antennas to increase the capacity of the wireless network by improving link quality [2].

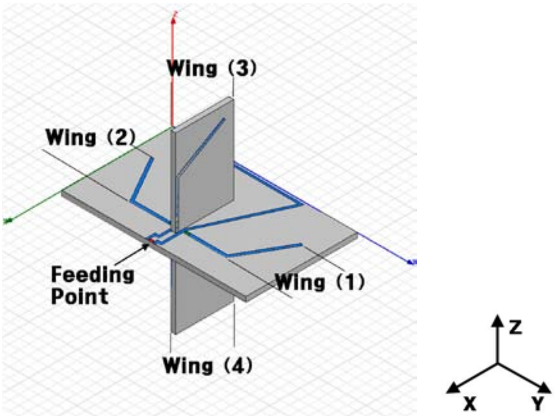
In this paper, we propose a reconfigurable beam steering 3D antenna for intelligent antenna system. The proposed antennas are designed to small electronic devices which need intelligent antenna system in future ubiquitous society. The proposed antenna is combined structure of dipole and loop antenna. It is known that the combined antenna has a directive radiation characteristic when two antennas are excited properly [3]-[4]. The antenna structure is very simple 3D structure. The switches are inserted on the connection parts between dipole and loop antenna as shown in Fig.1. By changing on/off states of switches, the combined structures of two antennas are varied. This various antenna configurations can steer the radiation beam direction(θ and ϕ). Simulation results confirmed the steering characteristics by using four imaginational switches. The proposed antenna can change the direction of the maximum gain in the x-y plane (0°, ±50°) and x-z plane (0°, ±50°). The proposed antenna operates in 2.6GHz ~ 2.65GHz (VSWR < 2). It was showed peak gain of the antenna is 1.94 ~ 2.48dBi.

Ⅱ. Antenna design

The antenna configuration of the proposed antenna is shown in Fig. 1 (b). The overall antenna shape is cross structure. The cross structure consists of one loop antenna and two dipole antennas. The top view of loop antenna and one dipole with two switches is shown in Fig. 1 (a). The triangular shape is for loop antenna and two wings in the +y-axis direction (wing 1) and –y-axis direction (wing 2) are for dipole antenna. Traditional circular loop was transformed to triangular loop antenna to improve return loss and gain [5]. The switches are located at the position between dipole antenna and loop antenna connection part. Therefore, one dipole (wing 1 and wing 2) is located at the y-z plane and the other dipole (wing 3 and wing 4) is located at the x-z plane. The feeding point is shown in Fig. 1 (b). The loop antenna is connected to the feeding point all the cases and the wings (dipole parts) are connected or not depend on switch on/off configurations. Fig. 1 (b) shows the combined antenna that put together the parts. The points of contact were set up the imaginational switches. The antenna size of the planar shape is 32 mm x 23 mm and the size of the 3D cross shape antenna is 32 mm x 23 mm x 32 mm. Table 1 shows the possible six antenna configurations with four switches. Depending on the six combination, the symmetrical structure changes asymmetrical. Each switching case steers radiation pattern in different directions. It can make the propose antenna can generate adaptive radiation pattern for the intelligent antenna system.



(a)



(b)

Fig. 1 (a) Top view / side view of the proposed antenna (b) 3D structure of the proposed antenna

Table 1 Antenna configurations by the switch ON/OFF states

State	Switch (1)	Switch (2)	Switch (3)	Switch (4)
0	ON	ON	OFF	OFF
1	ON	OFF	OFF	OFF
2	OFF	ON	OFF	OFF
3	OFF	OFF	ON	ON
4	OFF	OFF	ON	OFF
5	OFF	OFF	OFF	ON

Ⅲ. Simulation and Measurement results

A full-wave simulation was performed using the commercial software Ansoft HFSS. Simulation results of the reflection coefficients (S11) are shown in Fig. 2.

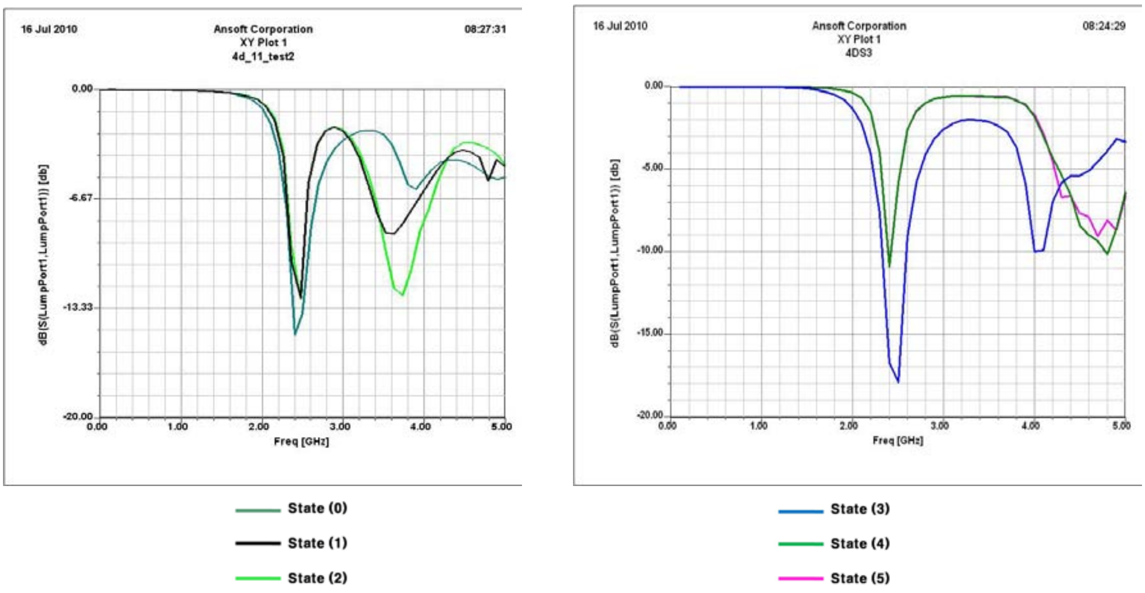


Fig. 2 Simulated S11 plots of the proposed antenna

Although the S11 plots are slightly changed depends on the switch on/off states, the S11 patterns are very similar each other. The centre frequency of the proposed antenna in state (0) case that switch 1 and 2 are on and switch 3 and 4 are off is 2.4 GHz with 180 MHz bandwidth (S11< -10 dB). The simulated radiation patterns are shown in Fig. 3.

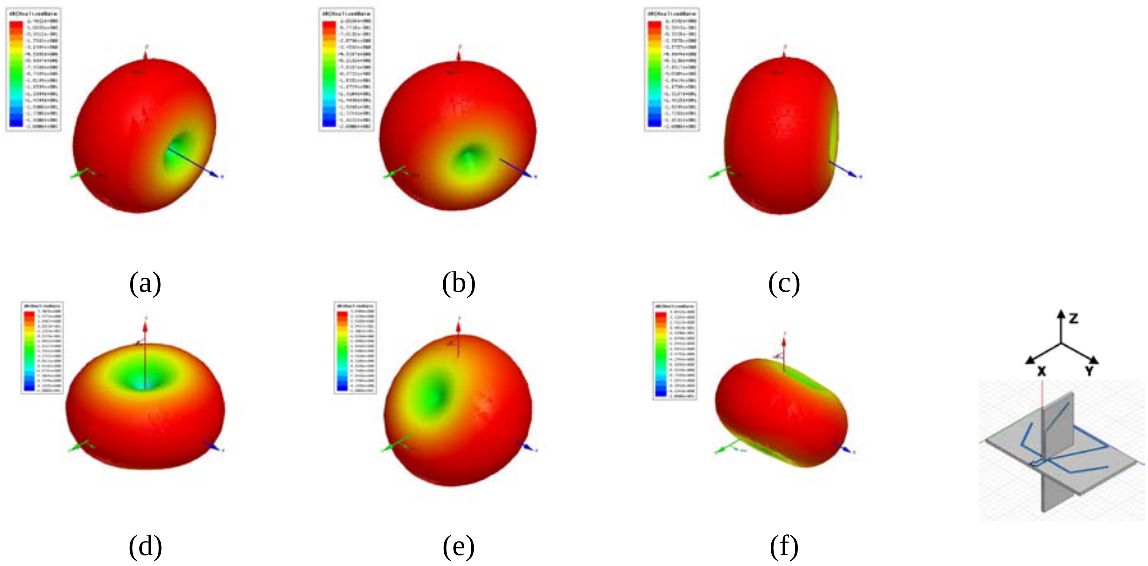


Fig. 3 Simulated radiation pattern (a) state 0, (b) state 1, (c) state 2, (d) state 3, (e) state 4, (f) state 5

In the figure, the directions of the radiation patterns are clearly changed by operating the switch combinations. The maximum gain of 2.35dBi appears at $\phi_{max} = 0^{\circ}$ in state (0). The gain in the direction of maximum radiation, for switch (1) shorting case, is found to be staying at 1.98 dBi at $\phi_{max} = 330^{\circ}$. State (2) generates a tilted beam, having direction of $\phi_{max} = 330^{\circ}$ and the maximum gain of 1.83 dBi. The maximum gain of 2.86dBi appears at θ_{max} = 90°. The gain in the direction of maximum radiation, for switch (3) shorting case, is found to be staying at 1.71 dBi at θ_{max} = 130°. State (5) generates a tilted beam, having direction of θ_{max} = 50° and the maximum gain of 1.69 dBi.

The antenna is implemented using the standard printed circuit board (PCB) technology. The substrate is 32mm×32mm×23mm FR-4 with a thickness of 1mm. Fig. 4 shows the photograph of the antenna. Fig. 5 shows the return loss of the antenna by the switching states. All of the states operating at near 2.6 GHz. The bandwidth is about 40 ∼ 50 MHz (S11 < -10dB). The proposed antennas are measured in the anechoic chamber. Simulated and measured patterns are in fairly good agreements with showing beam steering characteristics based on the switch on/off configurations.

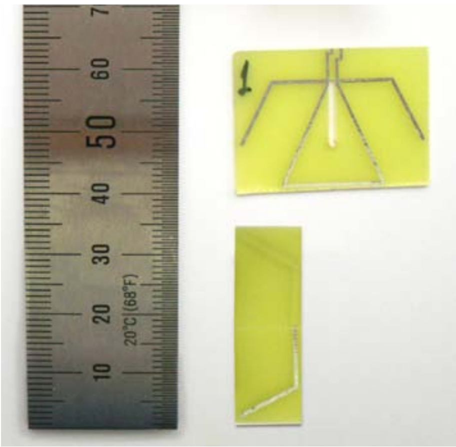


Fig. 4 Photograph of the proposed antenna

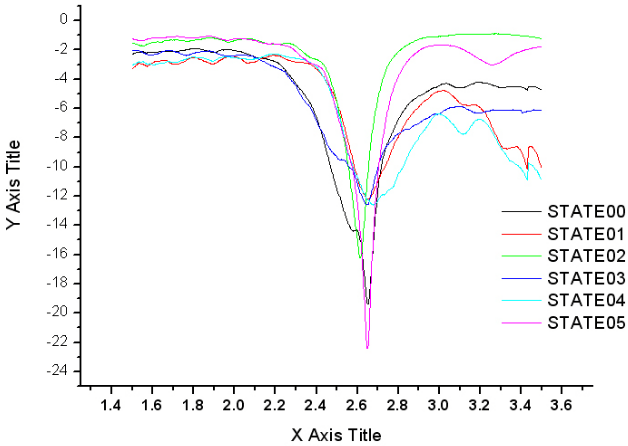


Fig. 5 Measured return losses

Ⅳ. Conclusions

In this paper, we propose a reconfigurable beam steering 3D antenna for intelligent antenna system. Four switches are inserted in the proposed antenna to generate beam steering characteristics. The switch configurations provide the modified antenna structures and changing the current distributions on the antenna, and thus controlling the direction of the radiated beam. The operating frequency of all the states is 2.6GHz. The gain, which is approximately 2dBi, stays uniform within ± 1 dBi variation and the VSWR remains within an acceptable limit of 2 for all of the switching cases.

Acknowledgments

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References

[1] A. Alexiou, M. Haardt, "Smart antenna technologies for future wireless systems: trends and challenges", IEEE Communications Magazine, vol. 42, no. 9, pp. 90-97., Sep. 2004.
[2] Ojanpera, T, Prasad, R, "An overview of third-generation wireless personal communications", IEEE JOURNALS, vol. 5, no. 6, pp. 59-65. Dec. 1998.
[3] Yougjin Kim, Chang won Jung "Small UWB Antenna with Combination of Electric-Magnetic Radiators", Korean Institute of Electrical Engineers, vol.58, no. 3, pp. 33~37, 2009.
[4] D.H. Kwon, “On the radiation Q and the gain of crossed electric and magnetic dipole moments”, IEEE Trans. Antennas Propagat., vol. 53, no. 5, pp.1681-1687, May 2005.
[5] C. A. Balanis, Antenna Theory Analysis and Design, 2nd Ed., New York: John Wiley & Sons, pp. 249-250, 2001.