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Enhancement of Performance Utilizing Low Complexity Switched Beam Antenna

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***Abstract*—**To manage the demand of wireless communication that has been dramatically increased, switched beam antenna in smart antenna system is focused. Implementation of switched beam antennas at mobile terminals such as notebook or mobile handset is a preferable choice to increase the performance of the wireless communication systems. This paper proposes the low complexity switched beam antenna using single element of antenna which is suitable to implement at mobile terminal. Main beam direction is switched by changing the positions of short circuit on the radiating patch. There are four cases of switching that provide four different directions of main beam. Moreover, the performance in terms of Signal to Interference Ratio when utilizing the proposed antenna is compared with the one using omni-directional antenna to confirm the performance improvable.

***Keywords*—**Switched beam, shorted circuit, single element, signal to interference ratio.

I. Introduction

WIRELESS communications have a part of currently everyday life in most developed countries. To cope with the dramatically demand of users, several techniques are proposed. One technique that is capable of increasing the wireless system capacity is the switched beam antenna in smart antenna systems [1]. Switched beam antenna is consisted of antenna array, beamforming network, and beam selector. At the beamforming network, the main beam directed to designated directions is produced. Next, the beam having maximum signal strength is selected by beam selector. These antenna systems are relatively interesting as their implementation is not complicated. Moreover, switched bean antenna can reduce interference signals coming from neighboring areas as shown in Fig. 1 which is a comparison of radiation patterns of omni-directional antenna and switched beam antenna. As we can see, it cannot only reduce interference signal coming from neighboring areas and neighboring signal points but can also enhance the signal in desired direction when switched beam antenna is applied in the system.

From the mentioned motivation, some examples from literatures for beam switching using single antenna element are discussed as follows. The work presented in [2], [3] show beam adaptive single arm rectangular spiral antenna with switches and a low profile tilted beam single arm spiral antenna on a high impedance surface for beam steering applications.

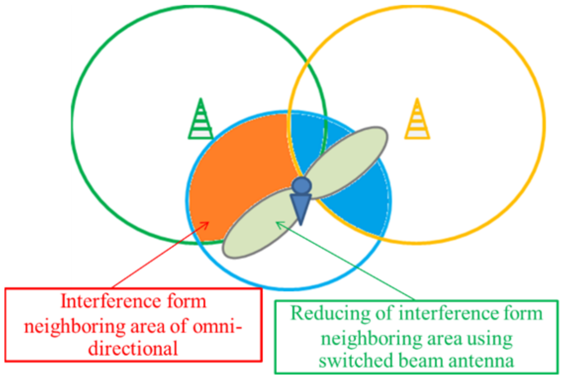

Fig. 1 Comparison of radiation patterns of omni-directional antenna and switched beam antenna

The antenna in these works has four feeding points where the radiation patterns can be steered by changing the feeding points. This is not practical as the feeding network is relatively complex. The work proposed in [4] has demonstrated performance evaluation of a low-cost switched-beam antenna for WLAN users. This work proposed single octagonal patch antenna which is capable of beam switching for four directions by shorted-circuit terminations at edges of the patch. The average gain of all directions is 3.48 dB. Moreover, the work presented in [5] has revealed low profile switched beam utilizing a ring-parasitic antenna. Beam direction can be changed by shorted circuit on difference small circular elements of parasitic ring which eight different directions are obtained. The average gain of eight directions is 4.758 dBi. However, the parasitic ring is rather complex structure.

The rest of this paper is as follows. After brief introduction, the proposed antenna designed is discussed in Section II. The structures of antenna and shorted-circuit switching are disclosed. Next, computer simulation is performed to show its beam switching capability in Section III. In addition, the performance in term of Signal to Interference Ratio (SIR) is revealed. Finally, Section IV concludes the paper.

II. Switched Beam Configuration

Microstrip patch antenna with circular radiating patch is considered on this paper. The circular size can be expressed by

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$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \quad (1)$$

where

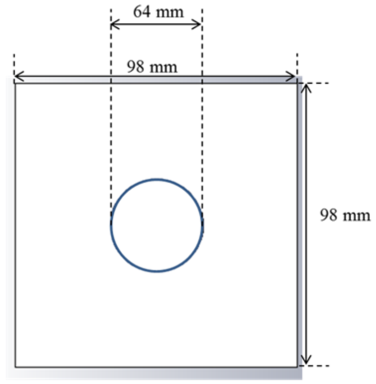
$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

where f_r is the resonant frequency, ε_r stands for the dielectric constant, and the height of substrate h in cm. From (1), a is 17.046 mm when ε_r is 4.3, the height of substrate is 2.00 mm and resonant frequency is 2.45 GHz that is small of size, thus there is low gain of antenna. To enhance the gain of antenna, size of radiating circular patch is increased. Therefore, the size of $2a$, which is 34.093 mm, is used on this paper. Next, the SMA feed probe is attached from one side through another side at the patch center which is symmetrically positioned along the E-plane.

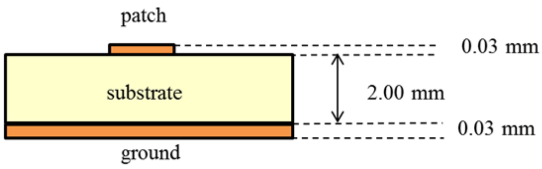
Next, the beam switching is controlled by shorted circuits at edge of the radiating patch. However, size of ground plane, size of substrate and positions of shorted circuit are influenced of the beam switching. Therefore, size of circular patch, ground plane, substrate and positions of shorted circuit are adjusted to beam switchable using CST Microwave studio. The configuration of the antenna after adjusting is shown in Fig. 2 which edge of circular patch is drilled to shorted circuit. There are eight holes, 1 to 8, of shorted circuit as shown in Fig. 3 that is four cases of beam switching which is discussed in the next section.

III. Simulation Results

There are four cases of shorted circuit, case A to case D, that provide four different main beam directions. In case A, positions 1 and 5 are open circuit and the other positions are shorted as shown in Fig. 4 (a). Also, current distribution and radiation pattern of this case are shown in Figs. 4 (b) and (c), respectively. As we can see, current distribution and main beam directions are depended on the open circuit positions which are 0° and 180° in case A. Next, positions 2 and 6 are open so called case B as shown in Fig. 5 (a). Also, current distribution and radiation pattern are shown in Figs. 5 (b) and (c) where main beam directions are 45° and 225°. In case C, positions 3 and 7 are open. Main beam directions are 90° and 270° and structure, current distribution and radiation pattern are shown in Figs. 6 (a)-(c), respectively. In the last case, case D, positions 4 and 8 are open, that provide main beam direction of 135° and 315° as shown in Figs. 7 (a)-(c). In addition, the average gain of antenna when case A to case D are applied is 5.495 dBi as described in Table I. Please note that gains of case A and case C are higher than gains of case B and case D due to the configuration of square substrate and ground plane where positions of shorted circuit the same direction of the corners of substrate and ground plane. However, this low complexity switched beam antenna is able to confirm its beam switching capability.



(a)



(b)

Fig. 2 Configuration of switched beam antenna (a) top view and (b) side view

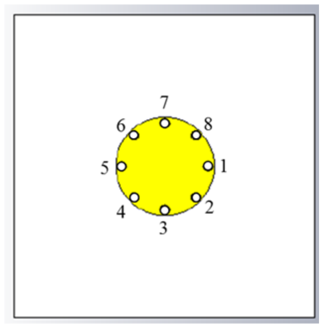
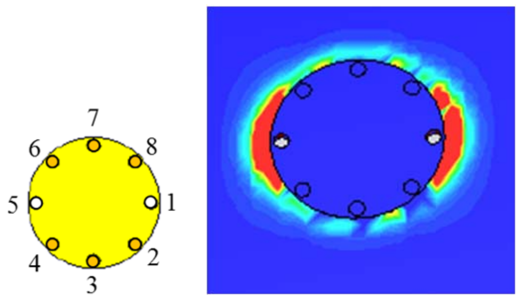
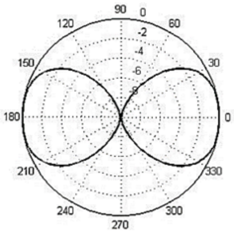


Fig. 3 Positions of shorted circuit

Next, the performance in term of SIR is revealed when distance between adjacent cell is assumed to be 1000 to 3000 meters. Path loss effect in wireless channel between users and access point is also taken into account as follows

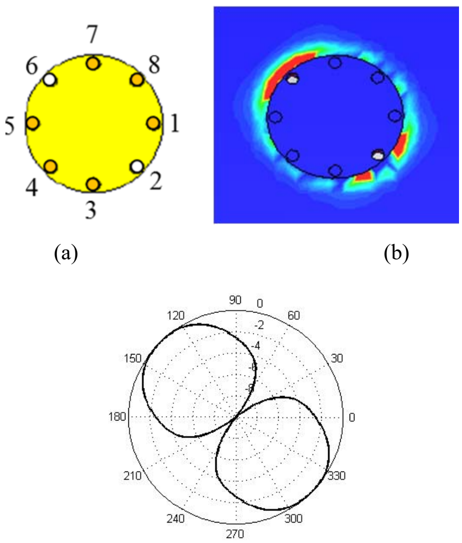


(a) (b)



(c)

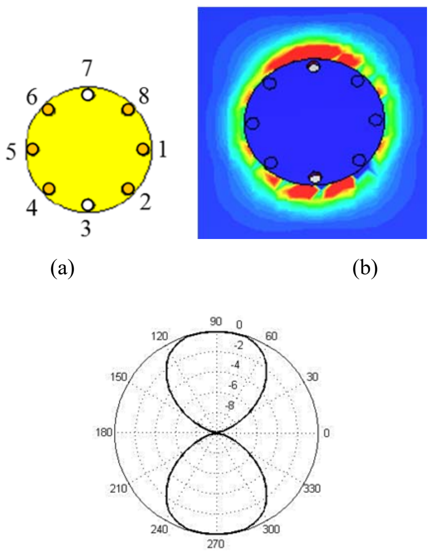
Fig. 4 (a) Configuration, (b) current distribution and (c) radiation pattern of case A



(a) (b)

(c)

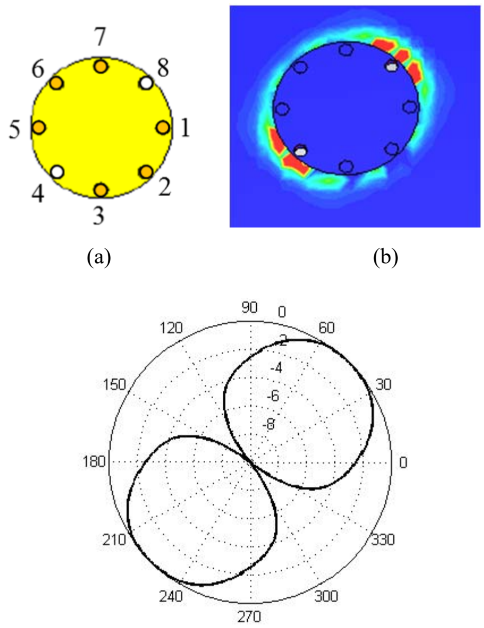
Fig. 5 (a) Configuration, (b) current distribution and (c) radiation pattern of case B



(a) (b)

(c)

Fig. 6 (a) Configuration, (b) current distribution and (c) radiation pattern of case C



(a) (b)

(c)

Fig. 7 (a) Configuration, (b) current distribution and (c) radiation pattern of case D

TABLE I
POSITIONS OF SHORTED/OPEN CIRCUIT

Positions of shorted circuit	Case			
	A	B	C	D
1	**short**	open	open	open
2	open	**short**	open	open
3	open	open	**short**	open
4	open	open	open	**short**
5	**short**	open	open	open
6	open	**short**	open	open
7	open	open	**short**	open
8	open	open	open	**short**
Direction (°)	0, 180	45, 225	90, 270	135, 315
Gain (dBi)	6.24	4.75	6.24	4.75

$$PL = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) \quad (3)$$

where R is the distance between user and access point. The received SIR at i^{th} user can be expressed by

$$SIR_i = \frac{P_i g_i \left(10^{\frac{PL_i}{10}}\right)}{\sum_j P_j g_{i,j}\left(10^{\frac{PL_j}{10}}\right)} \quad (4)$$

where P_i and P_j are the transmitted powers serving to i^{th} cell and interfering j^{th} cell, respectively. g_i is the gain of antenna when i^{th} user received the signal from access point. In addition, $g_{i,j}$ is the gain between i^{th} user and j^{th} access point.

PL_i and PL_j are the propagation path loss from i^{th} access point and j^{th} access point to i^{th} user, respectively. The performance in terms of SIR when the proposed antenna is utilized to compare with the one using omni-directional antenna as shown in Fig. 8. As a result, the SIR can be clearly enhanced when utilizing the proposed switched beam antenna. This is because the interference signals can be eased when placing nulls to their directions.

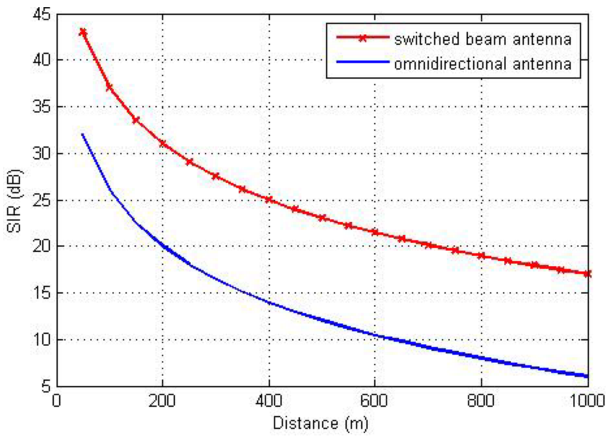


Fig. 8 SIR vs. distance between access point and users for the utilizing of switched beam and omni-directional antenna

IV. Conclusion

This paper proposes the single element switched beam antenna where beam direction is controlled by changing the positions of shorted circuit at edge of circular patch. There are four cases of shorted circuit that can provide four different directions. The performance in terms of SIR when utilizing the proposed antenna is compared with the one using omni-directional antenna. The obtained simulation results have revealed that the SIR is enhanced when applying a low complexity switched beam antenna.

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