The planar array antenna with two-dimensional radiation pattern reconfigurable elements

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***Abstract* - We propose a sparse array antenna using radiation pattern reconfigurable antenna. The sparse array radiates grating lobes on undesirable directions and decreases the gain on the desired direction. In order to overcome the problem, we apply a radiation pattern reconfigurable antenna to the element of the sparse array. A feature of the proposal antenna is applicability to two dimensional beam scanning. Though two dimensional beam scanning of a sparse array radiates grating lobes on various directions, the proposed antenna yield 9 types of element patterns and reduce grating lobes by selecting the element pattern. The gain improvement and the grating lobe reduction are demonstrated by numerical simulation.**

***Index Terms* —Phased Array Antenna, Sparse Array Antenna, Radiation Pattern Reconfigurable Antenna.**

1. Introduction

Phased array antennas (PAAs) have been used for radars and communication systems because of the advantage of electrical beam scanning. However PAAs have weaknesses of cost. If the desired gain is achieved by using small number of elements, the cost is reduced. A sparse array antenna, which uses wide element spacing, reduces the number of antenna elements and the cost. However normal sparse array radiates grating lobes (GLs) on undesired directions and decrease the gain on the desired direction.

One approach solving the problem is to apply radiation pattern reconfigurable antennas [1] to the element of the sparse array. This concept was proposed in [2]. We also proposed a radiation pattern reconfigurable antenna supporting uniform element spacing and large-scale PAAs in [3]. However they were limited to one dimensional beam scanning.

In this paper, we propose a sparse array antenna supporting two-dimensional (2D) beam scanning. If two dimensional beam scanning is assumed in the sparse array case, GLs are radiated on various directions. The proposed element yield 9 types of radiation patterns and reduce grating lobes by selecting the adequate element pattern. It is based on the patch antenna and uses four parasitic elements with switches to change the radiation patterns. The antenna structure is shown and the gain improvement and the grating lobe reduction are demonstrated by numerical simulation.

2. Array configuration and proposed element antenna

A. Concept of a sparse array antenna

PAA configuration in this study is shown in Fig. 1. As with common PAAs, the main beam is formed on the desired direction by using phase shifters. In a sparse array case, GLs, which are not shown in the figure, are radiated. In addition to beam scanning by the phase shifters, the element pattern increasing the gain on the desired direction and reducing GLs is adopted. Because 2D beam scanning creates GLs on various directions, multiple element patterns are required and most suitable pattern of them is selected according to the scanning angle.

B. Element antenna

Fig. 2 shows the structure of the proposed antenna element. The element antenna consists of the patch antenna and four parasitic elements with PIN diode switches.

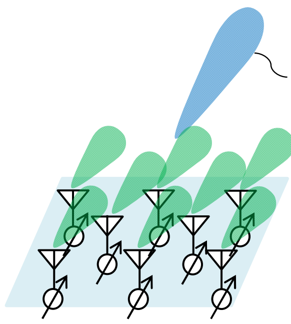

Fig. 1. PAA configuration.

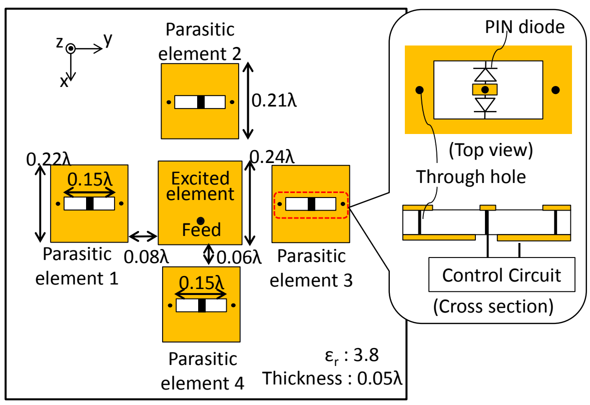

Fig. 2. Element antenna.

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PIN diodes are controlled by DC bias at antenna bottom as per Fig. 2, cross section. RF signal passes through PIN diodes in case of ON state. On the other hand, it bypasses around the slot structure in case of OFF state. Because the radiation phases from the parasitic element are different in these two states, various radiation patterns can be obtained by changing switch states. Because a parasitic element with ON states mainly acts as a director, the parasitic element according to the scanning angle is set to ON state. When the scanning angle is diagonal direction, multiple parasitic element can be set to ON.

3. Numerical simulation

We use an array configuration as per Fig. 3. GLs arise in the wide angle beam scanning. However, approximately 30% of elements are reduced compared with standard PAA which GL does not arise when ±30° is assumed as the coverage. The simulated element patterns are shown in Fig. 4. Various patterns can be obtained. Though only one quadrant and boresight patterns are shown, the proposed antenna can yield 9 patterns because of symmetry. Fig. 5 (a) indicates adequate element pattern mode yielding maximum gain for each direction. (b) shows its gain. Note that the gain in (b) cannot be achieved simultaneously across all angles. However, because PAA requires one scanning direction at once, the gain can be achieved by selecting the element pattern mode according to the scanning angle.

Radiation patterns of total array in Fig. 3 are shown in Fig. 6. The scanning angle is 2D; azimuth 30° and elevation 30°. (a) plot is the proposal which the element pattern of Fig. 4 (b) is applied. Fig. 6 (b) is the case without parasitic elements for comparison. The element spacing of both cases is identical. In (b), high GLs are observed and the gain of the desired angle is decreased. On the other hand, the proposed antenna (a) decreases GLs and drastically improves the desired gain.

4. Conclusion

We proposed 2D radiation pattern reconfigurable antenna for 2D beam canning sparse array antennas. We showed that the proposed antenna yielded 9 types of element patterns and it improved the gain across coverage. The array pattern showed GLs reduction and the gain improvement compared with normal sparse array without parasitic elements.

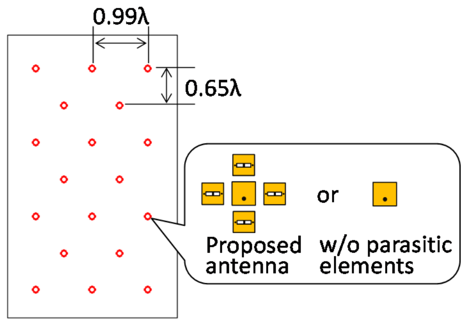
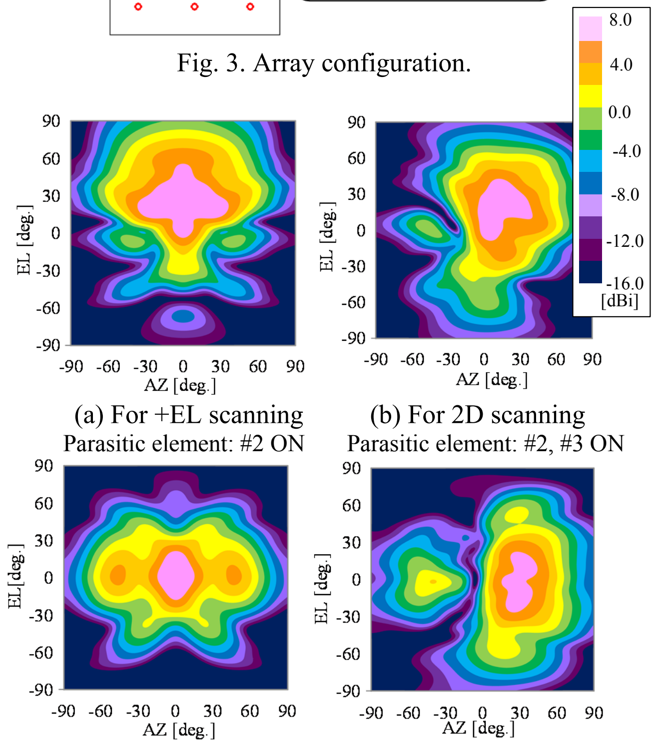


Fig. 3. Array configuration.



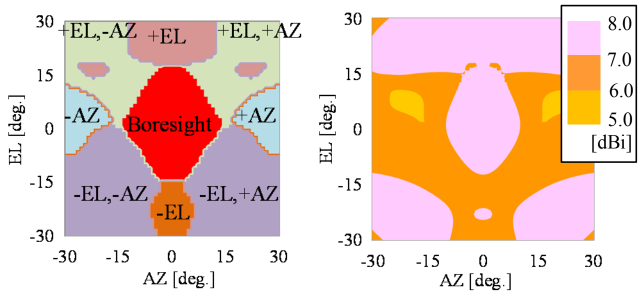
(a) For +EL scanning
Parasitic element: #2 ON

(b) For 2D scanning
Parasitic element: #2, #3 ON

(c) For Boresight
Parasitic element: All ON

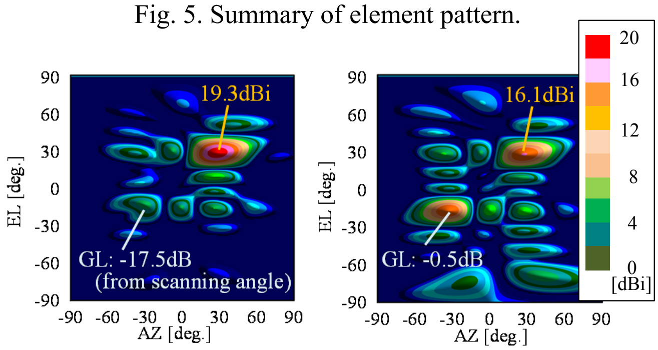
(d) For +AZ scanning
Parasitic element: #3 ON

Fig. 4. Array Element patterns.



(a) Selected antenna mode (b) Maximum element gain

Fig. 5. Summary of element pattern.



(a) w/ parasitic elements (b) w/o parasitic elements

Fig. 6. Array patterns (scanning angle: AZ=30°, EL=30°).

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