# Phased array of switched beam elements and application

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***Abstract* – This paper presents a two-element phased array antenna. The phase shifter for each element has one bit and each element has four beam directions. The suitable distance between elements provides side lobe level of less than -10 dB and gain higher than 6.3 dBi. With this simple configuration, this array antenna is useful in modern wireless communications and sensing applications.**

***Index Terms* — phased array antenna, pattern reconfigurable antenna, printed Yagi-Uda antenna, beam steering reflectometer.**

## 1. Introduction

Phase array antennas are used in many satellite and cellular communications [1]-[2]. This extensive usability is owing to the capability in beams steering to desired directions and to create nulls for interference directions. In addition, the ability of these antennas can be used in radar application for measuring property of interesting targets [3]. An accurate measurement depends on gain of antenna, side lobe level and number of points to evaluate material. Therefore, a phased array antenna can be good candidate.

To develop a phased array antenna, many technologies have been developed for increasing gain of the antenna [4] and switching beams with less complicated feeding network [5]. If pattern reconfigurable antennas are applied as each element of the array antenna [6], it can reduce side lobes of the phased array antenna. Furthermore, pattern reconfigure-able antenna is convenient to control beam direction.

This paper presents a phased array of switched beam elements and application. Each element is pattern reconfigurable printed Yagi-Uda antenna [7]. The pin diodes are placed in both driven elements and parasitic elements. The beams switching are implemented by changing the status of pin diodes (On/Off). This antenna is connected to the power combiner through a one bit phase shifter.

## 2. Design

A phase array antenna is designed based on linear array principle. The elements of array are reconfigurable printed Yagi-Uda antenna. Its radiation pattern can reconfigure in four directions by switching driven elements and parasitic elements. The simulated gain of each direction is around 5 dBi and sidelobe level is about -8 dB. The detail of these elements has been elaborated in [7].

The proposed phased array is investigated with its geometry as shown in Fig. 1. The two elements are aligned as linear array where distance between element 1 and element 2 is indicated as *d*. The radiation patterns can be reconfigured by changing element patterns and phase shifters. The phase shifter for each element has one bit which operates at ±135.5°.

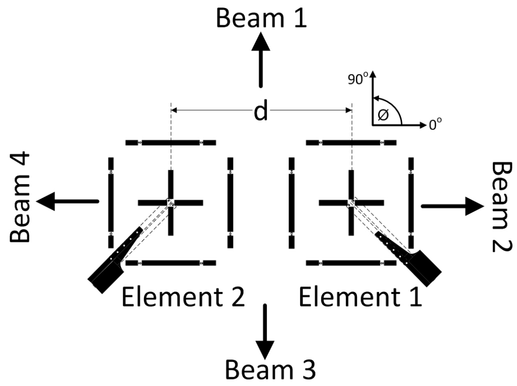


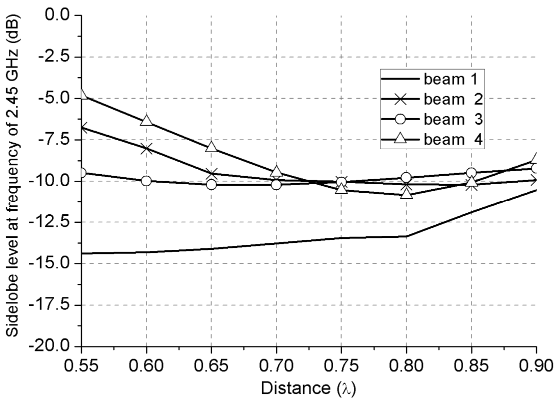

Fig. 1. Geometry of the proposed phased array antenna.

The phase excitation and beam direction of each element are shown in Table I. The elements must switch beam direction according to rectangular coordinate system in Fig. 1. Therefore, the operation of the phased array antenna is to implement beam switching in four directions.

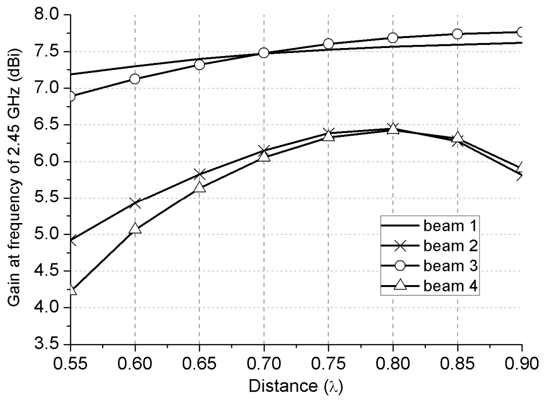
TABLE I
Operation of the phased array antenna

| Beam | Element 1 | | Element 2 | |
|---|---|---|---|---|
| | Beam direction | Phase excitation | Beam direction | Phase excitation |
| 1 | 90° | -135.5° | 90° | -135.5° |
| 2 | 0° | +135.5° | 0° | -135.5° |
| 3 | 270° | -135.5° | 270° | -135.5° |
| 4 | 180° | -135.5° | 180° | +135.5° |

Furthermore, the distance between both elements is adjusted in order to obtain the highest gain and the lowest sidelobe level. In Fig. 2 (a), it is found that distance of 0.75λ provides less than -10 dB of sidelobe level. In addition, in Fig. 2 (b), the distance between both elements of 0.75λ produces the almost highest gain for the four beams. Thus, this distance is the good option.




(a)




(b)

Fig. 2. The simulated results for various distances ( $d$ ) for four beams (a) Sidelobe level (b) Gain

## 3. Results

The results in Table I and Fig. 2 show good performance. The simulated radiation characteristics are shown in this section.

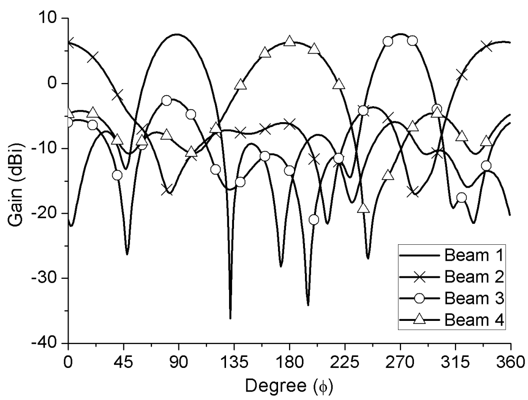



Fig. 3. Simulated radiation patterns for frequency of 2.45 GHz.

The array's radiation patterns are illustrated in Fig. 3. The main beams are steered to the desired directions. The maximum for main beams in beam 1, 2, 3, and 4 are at 88°, 355°, 270°, and 182°, respectively. The gain of the array antenna is simulated at the frequency of 2.45 GHz. The corresponding gains for each beam are 7.53, 6.39, 7.60, and 6.33 dBi, respectively. The sidelobe level of each radiation patterns in beam 1, 2, 3, and 4 are -13.44, -10.03, -10.06, and -10.53 dB, respectively. The half-power beamwidth of main lobes in beam 1, 2, 3, and 4 for horizontal plane are 36°, 57°, 33°, and 56°, respectively.

## 4. Application

Although there are a lot of applications in wireless communications, one of the application of interest is in beam steering reflectometer. We investigated a sensor for detecting fruit defection by measuring mean/standard deviation of the scattered wave from the fruit. The low value of this ratio indicated high standard deviation [8]. It means dielectric properties of that fruit is not uniform and is detected as defected fruit. This sensor requires a mechanical movement of the fruit. By using the beam steering antenna incorporated with appropriate reflector, the mechanical movement can be eliminated. This reflectometer is useful for fruit classification.

## 5. Conclusion

This paper has presented the design of a phased array of switched beam elements that switches main beam in four directions. The comprehensive analysis of this array has been obtained by changing element patterns and one bit phase shifters of ±135.5°. The optimal distance of elements provides average gain of almost 7 dBi at the frequencies of 2.45 GHz. In addition, the sidelobe level for all radiation patterns are less than -10 dB. This antenna can be applicable for communication system and sensor application.

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