A switch-beam circular array antenna using pattern reconfigurable Yagi-Uda antenna for space communications

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Abstract **– This paper presents a switch-beam circular array antenna using pattern reconfigurable Yagi-Uda antenna. A two-beam switching Yagi-Uda antenna is applied as an array element. The 3-element circular array is introduced to be able to switch the main beam in azimuth direction by switching the beam and shifting the excitation phase of array elements. The array antenna is designed at 2.4 GHz for drone or UAV radio controlling. The two-beam elements and 90°-shifted phase of excitation are applied to realize the proposed switched-beam array antenna. The simulated results show that the array antenna can provide 7 main beam directions covering a half azimuth plane (0° ≤ ϕ ≤ 180°) and gain of the array antenna is higher than 7 dBi.**

Index Terms **— switch-beam antenna, Yagi-Uda antenna, circular array antenna.**

1. Introduction

As the rapid growth of the wireless communications technology, the antenna technology, which is a key part of the wireless communications system, is increasingly developed by various techniques to improve the performance of antenna. Switch-beam antenna is one of the effective techniques. The switch-beam antennas have been developed continuously in many areas of wireless communications [1]-[6]. To improve the signal-to-interference ratio for indoor wireless communications, a phased array antenna of switch-beam elements was proposed in [1]. A switchable multiple beam planar array antenna was implemented for GSM-UMTS base station [2]. The switch beam antennas for WLAN application were introduced in [3, 4]. For digital TV applications, a four-beam pattern reconfigurable Yagi-Uda antenna was presented to improve the received signal on moving vehicles [5]. Subsequently, the 2-element phased array of the pattern reconfigurable Yagi-Uda antenna was applied to a sensor system for quality control of agricultural products [6]. In addition, the switch-beam antenna is introduced to the space communications for the drone or UAV radio controlling system. The radio control distance is supposed to be extended by increasing tracking performance of the antenna. Consequently, the 3-element phased array of pattern reconfigurable Yagi-Uda antenna is proposed in this paper. The design parameters and simulation results of the radiation characteristics and the $|S_{11}|$ of the proposed array antenna are presented.

2. Design

A switch-beam array antenna is introduced by applying the four-beam pattern reconfigurable Yagi-Uda antenna [5] as an array element. However, the array element is simplified to provide only two-beam switching. So, only a driven element is required to be switched between two perpendicular directions. A director and a reflector of the Yagi-Uda antenna are fixed. The configuration of the array antenna is shown in Fig.1. Three array elements are arranged as a circular array on the *xy*-plane. Element 1, 2 and 3 are positioned at ϕ = 90°, 210° and 330°, respectively. The array antenna is designed to switch beam covering a half azimuth plane (0° ≤ ϕ ≤ 180°). Element 2 and 3 are 45° rotated while Element 1 is not rotated in order to provide the beam in direction of ϕ = 90°. The parameters of the designed array antenna are shown in Table I.

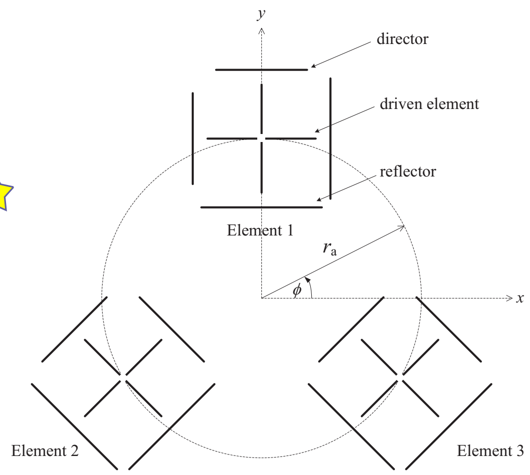

Fig. 1. Configuration of the array antenna.

TABLE I
Parameters of the Designed Array Antenna (at 2.4 GHz)

Parameters	Dimension
Length of director	0.37λ (46.25 mm)
Length of driven element	0.44λ (55 mm)
Length of reflector	0.49λ (61.25 mm)
Element spacing	0.28λ (35 mm)
Array radius	0.65λ (81.25 mm)

3. Simulated Results

According to the parameters of the designed array antenna as shown in Table I, the array antenna is simulated at the operating frequency of 2.4 GHz. The antenna is simulated by 4NEC2 simulator [7]. The antenna is modeled in free-space and with the wire radius of 0.5 mm. By switching the beam and shifting the excitation phase of the array elements, the switch-beam of array antenna can be carried out as shown in Table II. It is found that the beam direction of Element 1 is fixed at $\phi = 90°$ while the beam directions of Element 2 and 3 are switched between the directions of $\phi = 45°$ and $\phi = 135°$. Also, the excitation phase of array element is shifted by only one value of 90°. The simulated results show that the array antenna can provide 7 main beam directions covering a half azimuth plane. More than 7 dBi gain are obtained. Fig. 2 shows the simulated azimuth radiation patterns in a half azimuth plane ($0° \leq \phi \leq 180°$).

The $|S_{11}|$ of the array antenna is calculated by assuming that the array elements are connected to a lossless power combiner. Also, the impedance at the output of the power combiner is tuned to be matched at the designed frequency of 2.4 GHz. The calculation results of the $|S_{11}|$ of the array antenna for each beam direction are shown Fig. 3. The $|S_{11}|$ is calculated over the frequency range from 2.3 to 2.5 GHz. $|S_{11}|$ of less than -25 dB is obtained over the frequency range. The $|S_{11}|$ of -44.88 dB at 2.4 GHz is observed in case of 130° beam direction (Beam #6), which provides the highest gain of 9.54 dBi. In case of 30° beam direction (Beam #1), which provides the lowest gain of 7.11 dBi, the $|S_{11}|$ of -37.24 dB at 2.4 GHz is observed. For the cases of 50° and 150° beam directions (Beam #2 and #7), the $|S_{11}|$ at 2.4 GHz will be -41.45 dB and -37.38 dB giving the gains of 9.34 and 7.19 dBi, respectively. Also, the cases of 75°, 90° and 105° beam directions (Beam #3, #4 and #5), the gains are 8.31, 8.51 and 8.17 dBi and the $|S_{11}|$ at 2.4 GHz are -40, -38.14 and -39.42 dB, respectively. It is shown that the calculation results of the $|S_{11}|$ are accordant with the radiation characteristics results.

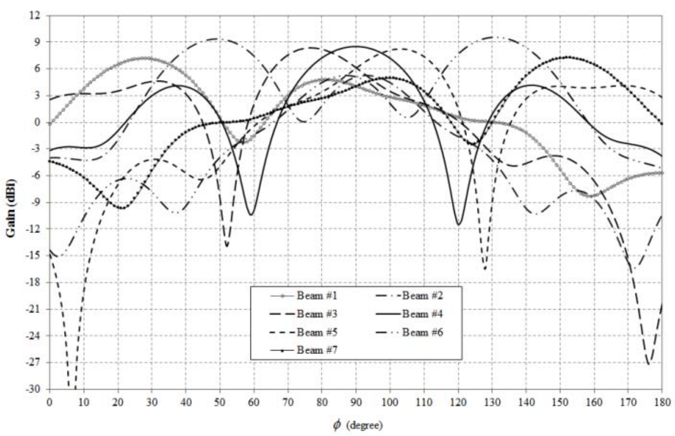

Fig. 2. Simulated azimuth patterns in a half azimuth plane ($0° \leq \phi \leq 180°$).

TABLE II

Simulated Radiation Characteristic of the Array Antenna

Beam	Beam direction/Excitation phase			Beam direction of array	Gain (dBi)
	Element 1	Element 2	Element 3		
#1	90°/90°	45°/0°	45°/0°	30°	7.11
#2	90°/0°	45°/0°	45°/90°	50°	9.34
#3	90°/0°	45°/90°	45°/0°	75°	8.31
#4	90°/0°	135°/0°	45°/0°	90°	8.51
#5	90°/0°	135°/0°	135°/90°	105°	8.17
#6	90°/0°	135°/90°	135°/0°	130°	9.54
#7	90°/90°	135°/0°	135°/0°	150°	7.19

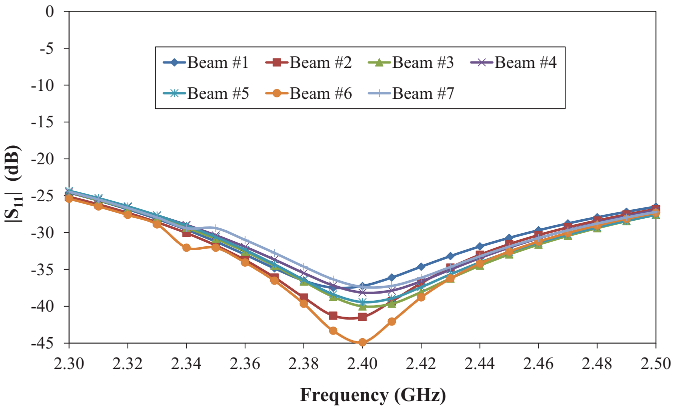

Fig. 3. Calculation results of the $|S_{11}|$ of the array antenna.

4. Conclusion

A switch-beam circular array antenna using two-beam switching Yagi-Uda antenna is proposed. The 3-element circular array is designed at the operating frequency of 2.4 GHz. Simulation results show that the array antenna can provide 7 main beam directions in a half azimuth plane ($0° \leq \phi \leq 180°$) by switching the beam of elements and 90° shifted excitation phase. Gain is higher than 7 dBi. The array antenna will be applied for drone or UAV controller to extend the radio control distance.

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