Design of a Quasi-Endfire Phased Array

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***Abstract* – A new method of designing a quasi-endfire phased array is presented in this paper. To improve antenna gain and realize quasi-endfire scanning, the five elements array of microstrip Yagi antenna located by steps distribution was made. The simulated results show that the array can realize quasi-endfire scanning from 60° to 80° off broadside direction in the *H*-plane with a high gain of 12dBi exhibiting superior low elevation angles scanning performance, which is of great importance in some applications such as satellite low-elevation tracking.**

***Index Terms* — Quasi-endfire, phased array, low-elevation scanning, steps distribution, high gain.**

I. INTRODUCTION

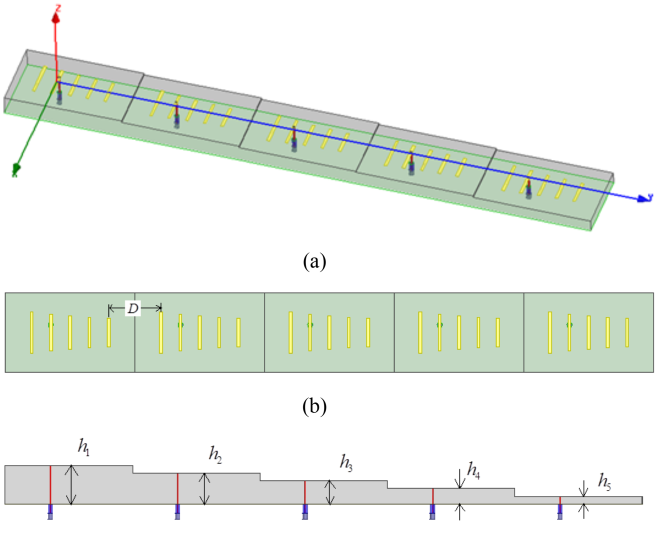
Phased arrays have been researched for many years and widely utilized in radar systems and wireless communications due to their rapid speed and high accuracy of beam scanning, etc. [1]. Especially, the classical broadside phased arrays technology has been developed considerably mature. However, in some special occasions such as applying in modern high-speed carriers, broadside phased arrays cannot satisfy the fairly stringent requirements about antenna size, weight and low aerodynamic drag, etc. Endfire antenna has a lot of excellent characteristics such as simple structure, easy production, low cost and low aerodynamic drag, which makes endfire antenna one of the best candidates for applying in varieties of high-speed mobile carriers.

Endfire antenna has been investigated for quite some years. Both Yagi antennas and log-periodic antennas are classical examples of endfire antennas [2] and numerous variants of these two kinds of antennas have been consistently proposed [3-4]. Kaneda et al. presented a microstrip-fed Quasi-Yagi antenna at X-band with a gain of 3–5 dB [5]. Lee and Chung presented a 38 GHz microstrip-fed Yagi antenna which uses 6 directors and the microstrip ground plane as a reflector to achieve a gain of 9.5 dB [6]. However, these traditional endfire antennas are middle gain antennas and are not suit to be applied in radar systems.

To improve antenna gain, using the endfire antenna as array element to form endfire arrays has been adopted. Most traditional endfire antenna arrays are along z or x axes direction (Fig.1 (a)). Although they have excellent directivity, the cross aperture figure is limited in some special application so it is very necessary to develop a new kind of array that the elements are located along its endfire direction. An endfire array was proposed to realize endfire pattern with high gain using printed Yagi antenna as antenna elements positioned along its endfire direction in ref. [7]. Another kind of endfire array was designed to obtain endfire pattern with high gain by locating the plat endfire antenna as array element along its endfire direction [8]. But these endfire arrays do not have the capability of scnanning.

In this paper, we designed a new endfire phased array antenna which has scan capability in some directions. Five microstrip Yagi antenna elements were located by steps distribution to reduce the blocking effects and the mutual coupling between antenna elements to realize high array gain. The simulated results demonstrate that the proposed endfire array can realize quasi-endfire scanning from 60° to 80° off broadside direction in the *H*-plane with a maximum gain of 12dBi, which is suit to be applied in some special applications such as satellite low-elevation tracking.

II. ENDFIRE ARRAY DESIGN



(a)

(b)

(c)

Fig. 1. Array structure with (a) schematic of the five elements array, (b) top view of the array and (c) side view of the array.

The proposed quasi-endfire phased array is composed of five microstrip Yagi antenna elements located by steps distribution, and its physical structure is shown in Fig. 1.The array operates at 5.8GHz and is printed on a 40mm × 275mm grounded dielectric substrate with permittivity (ε_r) of 2.2. From the top view of the array shown in Fig. 1(b), it is can be seen that five antenna elements are equidistantly positioned along the y-axis with adjacent edge spacing of D.

But they are located by steps distribution along the z-axis to reduce the blocking effects and the mutual coupling between antenna elements, as can be seen from the side view of the array in Fig. 1(c). The grounded dielectric substrate thickness corresponding to each element is marked by h_1, h_2, h_3, h_4 and h_5, respectively.

Fig. 2 shows the physical structure and parameters of the microstrip Yagi antenna element. Each array element is the same except the corresponding dielectric substrate thickness, which consists of a reflector, an active strip and three directors. The coaxial probe feed is selected and the probe can be moved along the x-axis to achieve the desire input impedance of 50 Ohm for impedance matching. The detailed parameters are: $L_r = 21$mm, $L_m = 19$mm, $L_{d1} = 17$mm, $L_{d2} = 16$mm, $L_{d3} = 15$mm, $W = 1.5$mm, and $S = 10$mm, respectively.

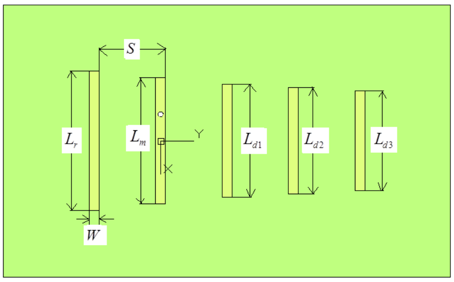


Fig. 2. Physical structure and parameters of the microstrip Yagi antenna element.

III. SIMULATED RESULTS

The proposed endfire array is simulated by the High Frequency Structure Simulator (HFSS). To reduce the mutual coupling and the blocking effects between antenna elements, large numbers of simulation and optimization about the adjacent edge spacing of D and the dielectric substrate thickness corresponding to each element were made. The optimized value of D is 10mm while the dielectric substrate thickness for each element is $h_1 = 11$mm, $h_2 = 10.5$mm, $h_3 = 10$mm, $h_4 = 9.5$mm, respectively.

Fig. 3 illustrates the active element patterns in the H-plane of the five-element endfire array. It is observed that the 3 dB beam coverage range of each active element pattern is relatively wide with a maximum gain of about 5 dBi, which is quite conductive to obtain low-elevation scanning pattern of the array with a high gain.

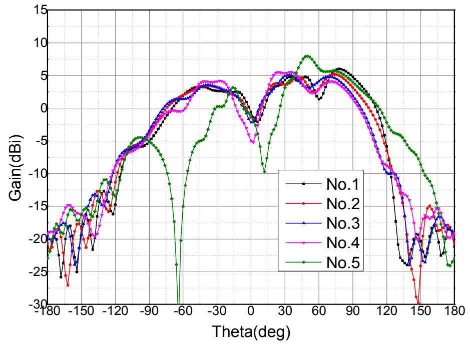


Fig .3. Active element patterns in the H-plane of the five-element array.

Fig. 4 displays the simulated scanning pattern in the H-plane of the endfire array. It is observed that the array can scan its main beam from $\theta_0 = 60^\circ$ to $\theta_0 = 80^\circ$ off the broadside direction with a maximum gain of 12dBi, which obtains low-elevation scanning performance. It is note the scanning beam could not reach completely endfire direction due to the reflection of the metal ground. Moreover, the PSLs are relatively high because of the large spacing between adjacent elements. How to reduce the PSLs needs to be studied by next.

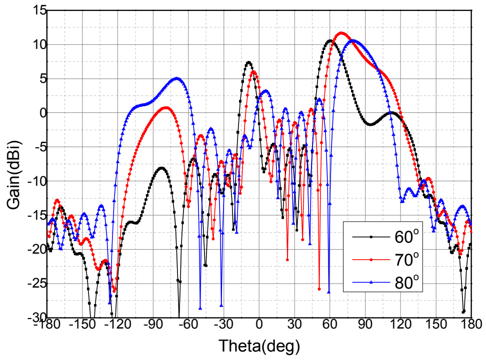


Fig .4. The quasi-endfire scanning pattern of the proposed array.

IV. CONCLUSION

In this paper, five-element microstrip phased array is designed to realize the quasi-endfire scanning from 60° to 80° off the broadside direction in the H-plane with a high gain of 12dBi through locating antenna elements by step distributions. The proposed endfire array can be applied in some special applications such as satellite low-elevation tracking.

ACKNOWLEDGMENT

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