Design of a Two-Dimensional Quasi-Yagi Array Antenna with Low Sidelobe

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***Abstract*—The paper presents the design of an end-fire array antenna with low sidelobe. The presented antenna operates on X-band consisting of 8×8 microstrip Quasi-Yagi antenna elements. In order to obtain -21dB sidelobe level and specific half power beamwidth, particle swarm optimization (PSO) is applied to optimize the power distributions of the feeding network and the element spacing. According to the optimized power distributions, two corresponding non-isolated microstrip power dividers are designed to feed the two-dimensional array. Finally, the array is fabricated and the measure results show a maximum sidelobe level of -18dB is achieved on the band from 8.9 to 9.6GHz with a minimum gain of 18.6dB.**

Keywords—Sidelobe level; Quasi-Yagi; PSO; array antenna

I. Introduction

In many radar applications, there is a strong demand for antennas of high gain and low sidelobe [1-2]. High gain can be easily obtained by using array technology. Likewise, a low sidelobe level can be also achieved by tapering feeding amplitudes [3]. Traditional synthesis methods of array antennas include Dolph-chebyshev [4], Taylor [5], Woodward-Lawson [6], etc. In these years, nature inspired computation has been widely applied to the synthesis of array with the development of computing technology, which has made a great success [7-8].

As a common antenna, end-fire antennas and arrays are widely used in communication and radar systems with the advantages of high gain and large bandwidth, such as Vivaldi antenna [9], end-fire dipoles [10] and Quasi-Yagi antenna [11]. Nevertheless, a poor performance will be achieved when array factor is involved with the synthesis of end-fire array antennas because of the strong mutual coupling [12-13] and covered antenna aperture resulting from the large scale in the direction of end-fire and relatively high gain. In this paper, a PSO method calling HFSS-MATLAB-API functions is applied to optimize the element spacings and the power distributions of two 1×8 Quasi-Yagi linear arrays which are disassembled from the 8×8 array [12,14]. And two corresponding non-isolated microstrip power dividers are designed to feed the array. Finally, the simulation and measure results of the 8×8 Quasi-Yagi array are given to verify this design.

II. Single Element Design

The single element used in this study is a microstrip Quasi-Yagi antenna. This antenna is printed on a 0.813mm-thick RO4003C substrate with a total dimensions of 26mm×29mm. It has a -15dB (S11) impedance bandwidth from 8.8 to 11.2GHz and a gain of 5.77dB at 9.2GHz. Fig. 1 shows the antenna geometry. Fig. 2 shows the simulated radiation pattern at 9.2GHz.

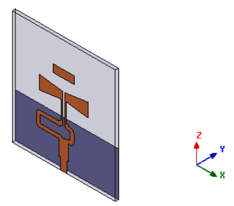
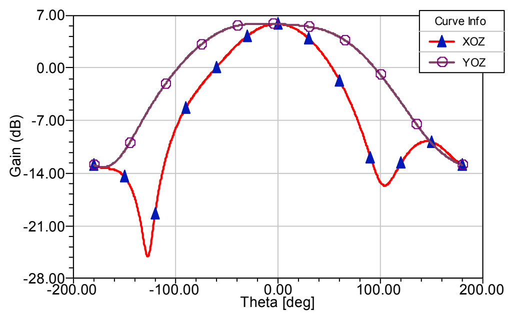


Fig. 1. Antenna geometry.

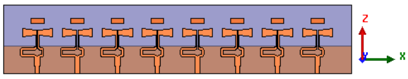


(b)

Fig. 2. Simulated radiation pattern.

III. Amplitudes Optimization and Feeding Network Design

In order to synthesize the radiation patterns of the 8×8 Quasi-Yagi array, Two kinds of corresponding linear arrays with eight Quasi-Yagi antenna elements are disassembled from the array. The geometries of the two linear arrays are shown in Fig. 3(a) and 3(b). One is placed along the x axis (xLArray, for short) and the other along the y axis (yLArray, for short). For minimizing the peak sidelobe level (PSL) and restraining the half power beamwidth (HPBW) of the two linear arrays in desired frequency band, PSO is used to optimize two groups of element excitation power amplitudes and the element spacings of xLArray and yLArray. According to the optimized power distributions and element spacings, two corresponding power dividers are designed.



(a)

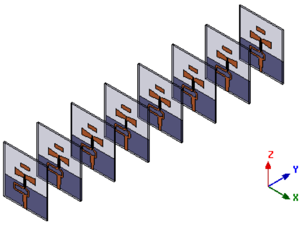


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Fig. 3. Two linear arrays. (a) xLArray. (b) yLArray.

A. Amplitudes Optimization

In this paper, the standard PSO is implemented by using math software MATLAB, of which the basic parameters are listed in Table I.

TABLE I. BASIC PARAMETERS OF PSO

Parameter	*Particle number*	*Iterations*	*Inertia weight*	*Acceleration constant c_1*	*Acceleration constant c_2*
Value	50	50	0.9	2	2

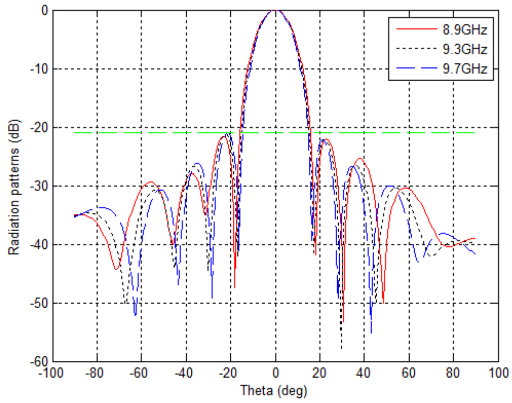
In the amplitudes optimization, the fitness function is defined as:

$$Fitness = \frac{u}{1+\left[\max\left[PSL(f_i)\right]-PSL_{goal}\right]^2} + \frac{v}{1+\left[HPBW-HPBW_{goal}\right]^2} \quad (1)$$

where the fi (i=1,2,...,M) refers to the sample frequency points; the PSL(fi) refers to the simulated PSL at the frequency fi; the HPBW refers to the simulated HPBW at the center frequency; the PSLgoal and the HPBWgoal represents the expected PSL and HPBW; u and v represent the weight of either part.

A random initialization method is used in the optimization. And u was set to 0.6 whilst v was set to 0.4 for the linear combination of the two objectives. The desired operating band is from 8.9 to 9.6GHz. Thus five sampling frequencies at 8.9 9.1 9.3 9.5 and 9.7GHz are used. The PSLgoal is given to -21. The HPBWgoal of xLArray is given to 13.6 while the HPBWgoal of yLArray is given to 11.

When starting the optimization, the Vbscript based on the linear array model needs to be recorded in advance in HFSS software. Then a series of operations can be completed by calling HFSS-MATLAB-API functions, including reading the Vbscript, starting HFSS software, changing array parameters, calculating directivity diagrams and so on. Fig. 4(a) and 4(b) show the optimized directivity diagrams of the two linear arrays. The amplitude distributions and element spacings of the two linear arrays are obtained and listed in Table II as well.



(a)

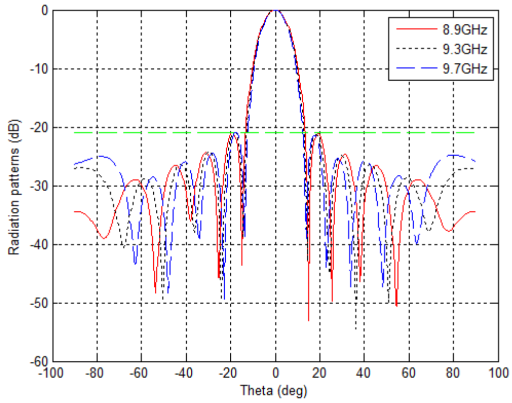


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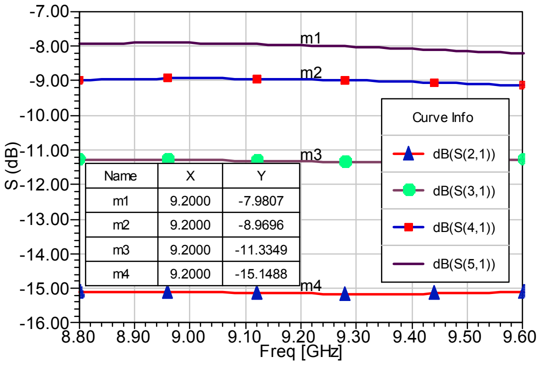
Fig. 4. The optimized directivity diagrams of the two linear arrays using PSO. (a) xLArray. (b) yLArray.

TABLE II. AMPLITUDE DISTRIBUTIONS OF THE TWO LINEAR ARRAYS

	Amplitude Distributions								**Spacing (mm)**
Number	1	2	3	4	5	6	7	8	
xLArray	1.0	2.38	4.01	5.1	5.1	4.01	2.38	1.0	17
yLArray	1.0	2.49	4.31	5.56	5.56	4.31	2.49	1.0	21

B. Feeding Network Design

To implement the tapered amplitude distributions listed in Table II, two non-isolated T-junction microstrip dividers are designed. The simulation results are given in Fig. 5(a) and 5(b), which agree with the amplitude distributions given in Table II.



(a)

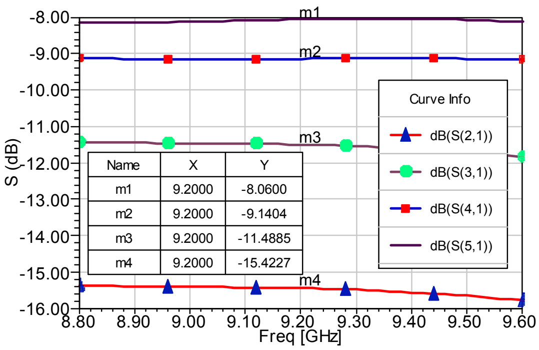


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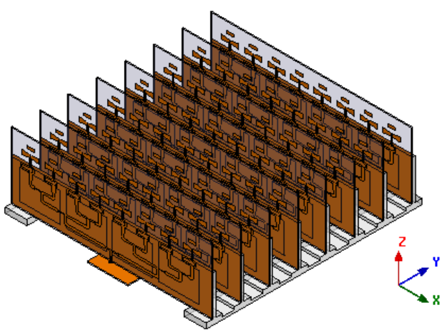
Fig. 5. The simulation amplitude distributions of the two dividers. (a) The feeding divider of xLArray. (b) The feeding divider of yLArray.

IV. Simulation and Measurement of the Two-Dimensional Array

The two-dimensional array is given in Fig. 6(a) with 8×8 antenna elements. And the prototype of the array is fabricated, which is shown in Fig. 6(b). The total dimensions are 148mm×179mm. The measured VSWR is given in Fig. 7. It can be seen that the array has a wide impedance bandwidth of more than 20%. Fig. 8 and Fig. 9 show the simulated and measured radiation patterns on the desired operating band. Gain against frequency is also measured and listed in Table III.



(a)

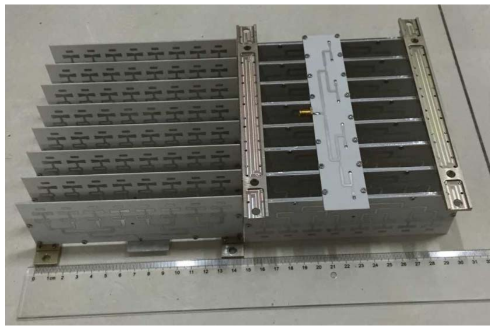


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Fig. 6. (a) Geometry of the array. (b) Prototype of the array.

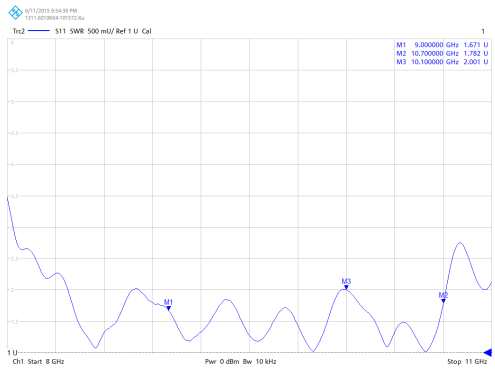
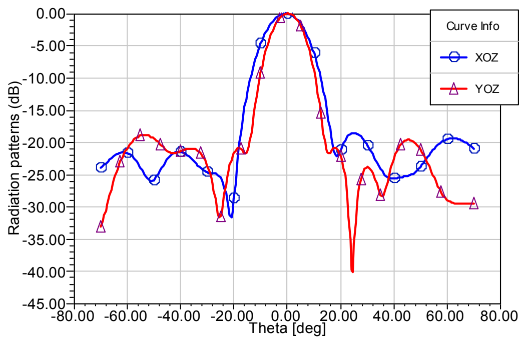


Fig. 7. Measured VSWR of the array.



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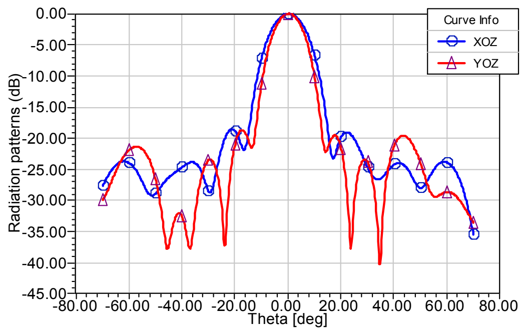

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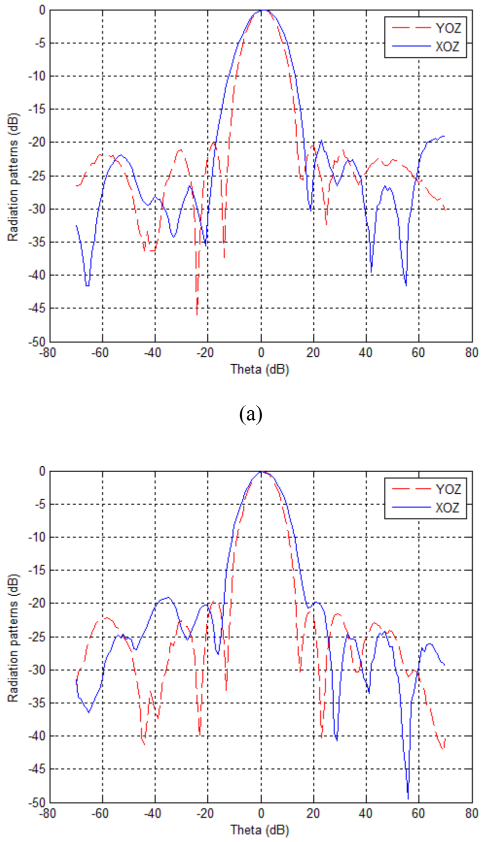
Fig. 8. The simulated radiation patterns. (a) 9.1GHz. (b) 9.4GHz.



(a)

(b)

Fig. 9. The measured radiation patterns. (a) 9.1GHz. (b) 9.4GHz.

TABLE III. GAIN OF THE ARRAY

Freq(GHz)		8.9	9.0	9.2	9.3	9.5	9.6
Simulated Gain(dB)		20.7	21.1	21.3	21.3	21.4	21.5
Measured Gain(dB)		18.6	20.1	20.2	19.8	20.3	19.8
Simulated PSL(dB)	XOZ	-18.5	-19.4	-19.3	-19.2	-19.8	-18.6
	YOZ	-19.7	-20.6	-20.4	-19.7	-20.1	-19.4
Measured PSL(dB)	XOZ	-18.0	-19.2	-18.4	-18.2	-19.1	-18.2
	YOZ	-19.0	-20.2	-20.4	-19.5	-20.6	-19.3

V. CONCLUSION

In this paper, a 8×8 Quasi-Yagi antenna array has been designed with low sidelobe on X-band. In order to obtain -21dB sidelobe level and restrain the half power beamwidth, the standard PSO is applied to synthesize the radiation patterns. And According to the optimized power distributions and element spacing, two corresponding power dividers are designed. Finally, the 8×8 array is simulated and fabricated. The measure results show that a maximum sidelobe level of -18dB has been obtained on the desired frequency band from 8.9 to 9.6GHz with a minimum gain of 18.6dB.

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