Large Waveguide Slotted Array With Shaped Patterns

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***Abstract*—Genetic Algorithms(GAs) is employed to synthesis the large fan beam shaped pattern waveguide slotted array. Waveguide phase shifters are used to compensate the definite phases for each waveguide. The whole array is divided into eight partitions to broaden the bandwidth. Full wave simulations confirm the design of the shaped pattern antenna that will be used in the altimeter payload.**

***Index Terms*—Genetic Algorithms, shaped pattern, waveguide slotted array**

I. Introduction

Waveguide slot array antennas have been widely due to the advantage of compact structure, light weight, high aperture efficiency, the easy control of aperture distribution [1-6]. Waveguide-fed slot arrays are increasingly used in numerous radar, remote sensing and communications applications. In practice, there is some need that for the antenna patterns with strongly shaped fan beam patterns. One of the key points in the design of a slotted waveguide array with strongly shaped beams is to find an aperture distribution which is realizable. Several methods have been used for the synthesis the shaped patterns [7-8], this paper present a new more flexible GAs method for the optimization. Different from the symmetrical patterns,the shaped one has special and sensitive demand on the phases of the feeding waveguides in addition to the amplitudes. The phase shifting network for each feeding waveguide are used to compensate the phase of each tilt slot. Elliott's design procedure for planar arrays is employed to synthesis this array.

II. GAs Optimization of Shaped Beam Pattern

Longitudinal slots are used as radiating elements of waveguide slot array antenna with broadside radiation. If appropriate aperture field distribution given, the desired patterns will be acquired. We use the Genetic algorithm to optimize array antenna array elements amplitude and phase. The amplitudes and phases are coded in binary. The antenna array works at Ku band,with the 22 rows and 152 columns elements. The pattern in the narrow beamwidth (152 elements) is symmetrical while that in the wide beamwidth (22 elements) has shaped demand. Heredity, mutation, crossover used to optimized the shaped beam patterns. However, due to the limited dimension for space antenna radar use, the most important goal factors are shaped patterns and gain, therefore the goal function can be expressed as antenna patterns (dB) at different angles. The crossover rate is 0.5, the mutation rate is 0.02, population is 50.

Different groups of the radiation slots amplitude and phase after the decoding of the binary can be found after GAs. In order to have high aperture efficiency of the antenna array, the maximum/minimum amplitude ratio among the radiation slots should not be too big; also, the max/min phase difference should be as small as possible to reduce the difficulty of phase compensation needed for the feeding network. The final group of amplitude and phase of the 22 elements is chosen for this antenna is tabulated in Table 1.

TABLE I. Amplitude and Phase of the Elements

Elements		1	2	3	4	5	6	7	8	9	10
Amp		0.20	0.20	0.20	0.25	0.2	0.27	0.2	0.2	0.2	0.42
Phase(°)		225	216	229	205	166	134	86	0	300	300
11	12	13	14	15	16	17	18	19	20	21	22
0.48	0.69	0.82	0.91	0.97	1	1	0.93	0.81	0.69	0.55	0.45
300	287	269	252	236	220	205	191	176	160	142	129

III. Shaped Beam Pattern Slotted Array Antenna

The antenna pattern using the amplitudes and phases of Table 1 is shown in Fig. 1, it is clear that the antenna has strong shaped curve due to the aperture distribution. In order to have relatively wider bandwidth, the waveguide slotted array radiation has 8 subarrays. The phase compensation network lie in the second layer (Fig. 2). The four coupling waveguide lie in the middle of the different subarrays on the third layer. The bottom layer is the feeding waveguide. The half height waveguide dimensions are chosen as 14.87mm*4mm for all the radiation, coupling, feeding and phase compensation networks. The baffle thickness is 0.84mm for the radiation waveguides, while the layer thickness is 0.8mm. All slots widths are 1.6mm, and the slots are ended by half circle with radius of 0.8mm. Elliott's design procedure for planar arrays is employed to synthesis this array.

The phase compensation network utilize the different width waveguide to meet the phase shift needed. Detailed structure of the phase compensation waveguide is shown in Fig. 3. The half height waveguides have been known to have no significant higher-order mode coupling in the junction regions near the tilted coupling slots. With this choice of waveguides, the design based on Elliott's approach generally needs no further iteration to account for higher-order mode

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coupling effect computed from a full-wave model. Full wave method FDTD is employed to find the normalized admittance and resonant length variation with frequency of an isolated slot (Fig. 4).Elliott's theory is utilized to seek out the radiating slots offsets and lengths. The coupling coefficient of each coupling slot can be obtained by Elliott's equations, then the FDTD is also used to find the coupling slots resistance and length variation with tilt angles (Fig. 5).

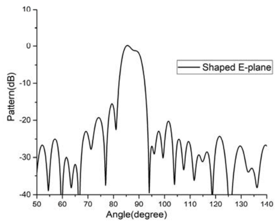

Fig. 1. Diagram of the shaping pattern.

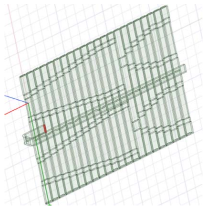

Fig. 2. Diagram of the antenna phase compensation structure.

Elliott's design technique reported gets simplified considerably for the infinite array coupling problem. The active conductance of each radiating slot is obtained by simple formula. Some expert suggests a value of total normalized active conductance of 2 for each radiating waveguide and a value between 2 and 3 for the total resistance in each feed waveguide. The total normalized active conductance is chosen as 2.

Fig. 3. Structure of the phase compensation waveguide.

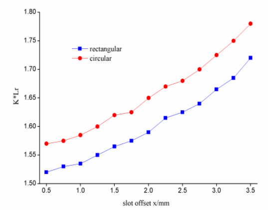

Fig. 4. The resonance length vs offset of the straight slots.

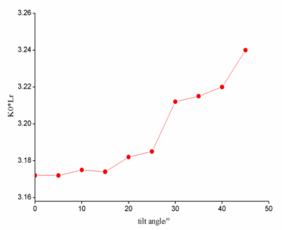

Fig. 5. The resonance length vs offset of the tilt slots.

Due to the fact that the radiating waveguide No.8 has the least phase value, therefore that phase is chosen as the base line. The final phase compensation waveguides can be seen in Fig. 2. The feeding network uses the 8 tilt slots coupling with the coupling waveguides. Finally, the whole array is fed by H-T feeding network.

IV. Simulation Results of the Antenna

The shaped beam pattern waveguide slotted array simulation is finished based on the HFSS full wave simulation. The antenna patterns are shown in Fig. 6. It can be seen that the shaped pattern has -18dB sidelobe level (SLL), while the SLL in the symmetrical plane pattern is about -25dB, in addition, the antenna has aperture efficiency of about 60%. All these results meet the specification for the altimeter demand.

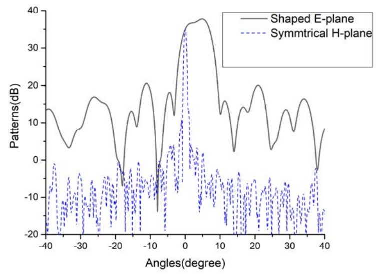

Fig. 6. Shaped patterns in main plane by simulation.

V. Conclusions

22*152 elements shaped beam pattern slotted array antenna is optimized and designed by GAs method. Full consideration and a rigorous analysis is given to the slots end shape and the thickness effect of waveguide. The array mutual coupling effects also influence the radiation, the H-T coupling network is used to realize the wideband characteristics. The full wave simulation showed that the side lobe levels of two principal planes are -18dB and -25dB respectively. The proposed antenna is very suitable for space-borne application.

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