# Pattern Synthesis Method for a Center Holed Waveguide Slot Array Applied to Composite Guidance

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***Abstract*-The circular waveguide slot array with a hole in the center is one of the key techniques to realize the shared aperture composite guiding. Due to the influence of the hole, a sound realization of low side-lobe pattern is the difficulty and key for this antenna. The waveguide broadside shunt slot array only can realize low side-lobe by controlling the distribution of the amplitude. And it needs to control the slot offsets to achieve the distribution of amplitude. But it is already difficult to realize low side-lobe for this configuration, and the influence of the slot offset will not be ignored. So in the paper, we propose a new pattern synthesis method, which combines genetic algorithm and Elliott's design method for slot array. And this method takes slot offsets and mutual coupling into account, then adjust the slots' parameter to achieve low side-lobe. The combination of the designation of array parameter and pattern synthesis not only realizes the low side-lobe pattern synthesis, also achieves the designation of the array parameters at the same time.**

## I. INTRODUCTION

Composite guidance is the research hot spot of the guidance technique, especially, the composite of the optics and microwave. Waveguide slot array has been widely used in bomb due to its excellent electric and mechanical performance. To fulfill the shared aperture composite guidance, a hole in the center of the circular waveguide slot array is needed to place the optical guidance equipment. But the center key slots are loss, which would increase the sidelobe level. And the more elements lost, the more exasperate of the far-field pattern.

It is hard to adjust the phases of the waveguide slots. Only amplitude can be adjusted by altering the slot offsets. So it is difficult to achieve low sidelobe while losing the key center elements. And traditional synthesis method rarely considered the slot offset effects. So in this paper, we propose a synthesis method which considers the effects of the slot offsets and the mutual coupler. This method combine the genetic algorithm[1] (GA) and Elliott's classic waveguide slot array designed method[2][3]. While the pattern is synthesized, the array slots' parameter will get.

## II. FAIRFIELD WITHOUT CONSIDER SLOT OFFSETS

Taking an X band (center frequency is 10GHz) waveguide slot array as example. The array model is shown in Fig1. The diameter of this circular antenna is 260mm, and the diameter of center hole is 40mm. So the four center slots are lost.

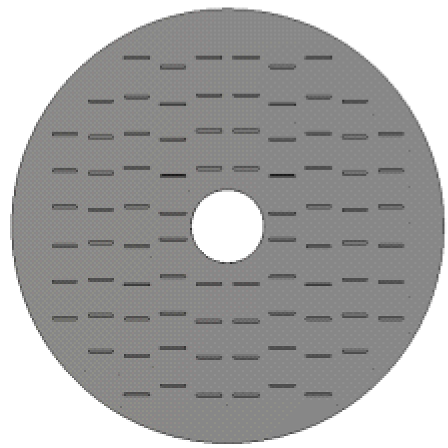


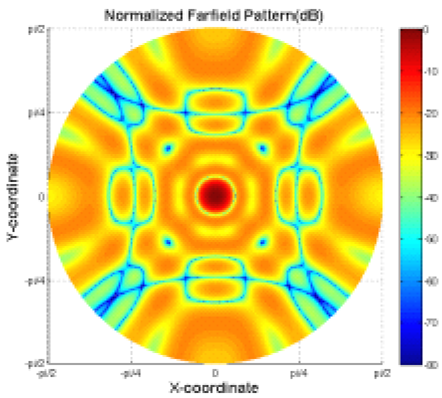
Fig.1. Center holed circular waveguide slot array.

Firstly, we synthesize a pattern with -20dB sidelobe level without considering the slot offsets using GA method. The amplitude distribution is shown in Table 1. And the farfield pattern with zero slot offsets is shown in Fig2. Fig2. (b) shows the sidelobe level is below -20dB. But in reality, the slot offset cannot be neglected. According to the amplitude distribution, we can calculate the slot parameters of slot offsets and slot length by using Elliott's method. And the real pattern is shown in Fig3. The sidelobe level is up to -17.6dB. It is not easy to realize low sidelobe while center key elements are losing. If we still neglect the slot offsets in pattern synthesis, the sidelobe level will not meet the demand in engineering.

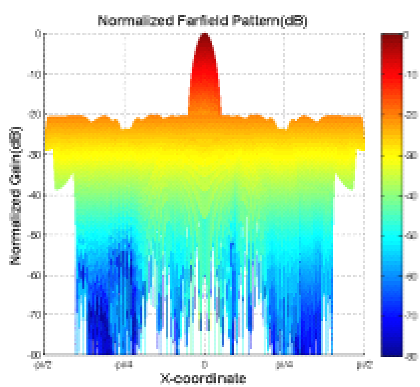
So we need to design a pattern synthesis method which should take slot offsets into account, and also consider the mutual coupler. Then the designed farfield pattern can be good accordance with the real farfield pattern.

Table I
Amplitude distribution of the quarter array without considering slots offsets.

| | | | | |
|---|---|---|---|---|
| 0.399 | 0.422 | 0.279 | - | - |
| 0.401 | 0.182 | 0.231 | 0.370 | - |
| 0.700 | 0.681 | 0.470 | 0.214 | 0.299 |
| 1.000 | 0.535 | 0.675 | 0.200 | 0.409 |
| - | 0.995 | 0.685 | 0.396 | 0.374 |



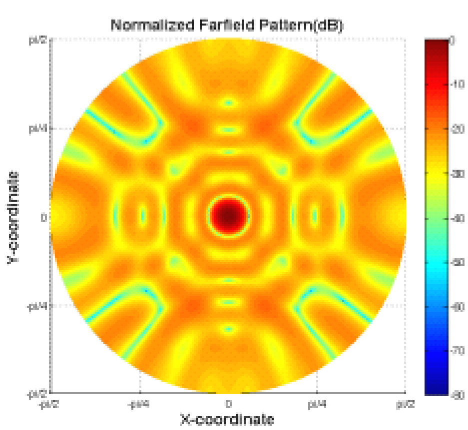

(a)



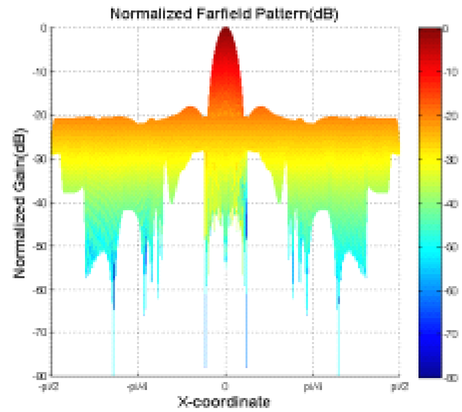

(b)

Fig.2. Antenna farfield pattern with zero offsets.

(a) top view (b) side view




(a)




(b)

Fig.3. Antenna farfield pattern with slot offset.

(a) top view (b) side view

## III. FARFIELD SYNTHESIS CONSIDERING SLOT OFFSETS

To take the slot offset into account, we design a pattern synthesis method. The flow chart is shown in Fig4. And the main process contains three steps.

Step 1： Calculate the amplitude distribution **Vs**, slots offsets **Ds** and slots length **Ls** by Using GA method. And we use formula (1) to calculate the initial slot offsets. This formula is deduced by Stevenson[4]. And gr is the normalized conductance, ds is the slot offset.

$$ds = \frac{a}{\pi}\operatorname{asin}\left(\left(\frac{gr}{2.09}\cdot\frac{b}{a}\cdot\frac{\lambda}{\lambda_g}\Big/\cos^2\left(\frac{\pi\lambda}{2\lambda_g}\right)\right)^{0.5}\right) \quad (1)$$

Step 2: calculating the array mutual coupling matrix and using Elliott's three formulas[3] to iterative compute the slots parameters and compensating the mutual coupling. Then new slot length matrix **Lsm** and slot offsets matrix **Dsm** are got.

Step 3: Judging if the results are convergent? If yes, the final results are got. If no, we turn to step 1 and substitute **Dsm** for **Ds** to recalculate the Vs. And till convergent.

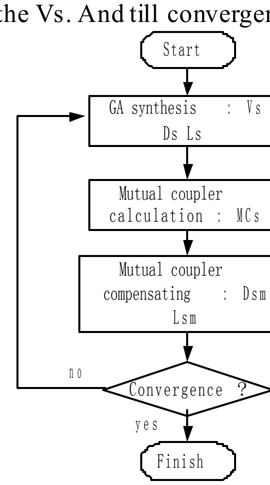
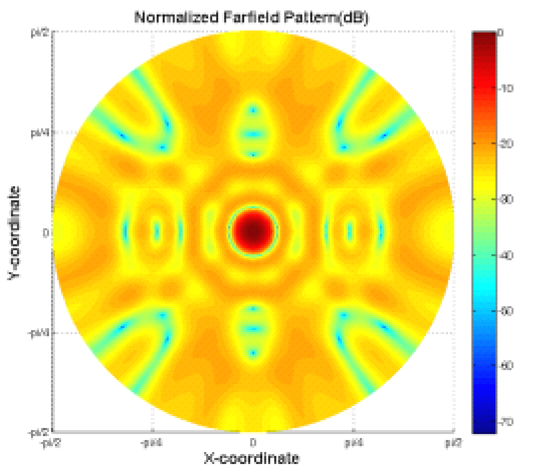



Fig.4. Pattern synthesis flow chart.

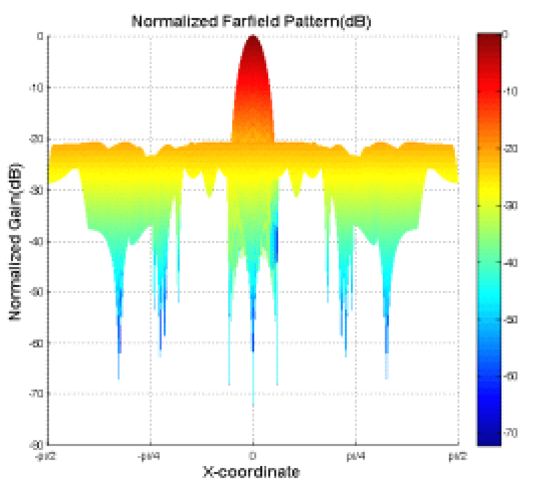
Using this method, we design a waveguide slot array. The amplitude distribution is list in Table 2. And the farfield pattern is shown in Fig.5. The sidelobe levels are all below -20dB.

Table II
Amplitude distribution of the quarter array considering slots offsets.

| | | | | |
|---|---|---|---|---|
| 0.280 | 0.230 | 0.200 | - | - |
| 0.298 | 0.309 | 0.200 | 0.220 | - |
| 0.597 | 0.470 | 0.427 | 0.237 | 0.200 |
| 1 | 0.523 | 0.586 | 0.209 | 0.333 |
| - | 0.897 | 0.596 | 0.335 | 0.351 |




(a)




(b)

Fig.5. Farfield pattern consider slot offsets. (a) top view, (b) side view.

## IV. CONCLUSION

This paper designs a pattern synthesis method for center holed waveguide slot array which is applied to composite guidance. This method combines GA and Elliott's method, and fully considers the possible factors which could affect the pattern property. Taking slot offsets and mutual coupling into account, so the results can be most close to the real condition. It is a effective method for center holed waveguide slot array designation.

## REFERENCE


[1] F. J. Ares-Pena, J. A. Rodriguez-Gonzalez, E. Villanueva-Lopez, and S. R. Rengarajan, Genetic algorithms in the design and optimization of antenna array patterns, [J]. IEEE Trans. Antennas Propagat. , 1999, vol.47, no.3, pp.506–510.

[2] R. S. Elliott, Improved design procedure for small arrays of shunt slots, [J]. IEEE Trans. Antennas Propagat. , Jan. 1983, vol. AP-31, pp. 48-53.

[3] R. S. Elliott and W. R. O'Loughlin, The Design of Slot Arrays Including Internal Mutual Coupling, [J]. IEEE Trans. Antennas Propagat. Sep. 1986, Vol. AP-34(9), pp. 1149-1154.

[4] J. L. Volakis. Antenna Engineering Handbook [M]. Fourth Edition, McGraw-Hill, 2007: Ch9.