Optimization of Smooth Walled Horn Antenna using Multilevel Fast Multipole Method

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***Abstract* –This paper presents an analysis and optimization method of smooth walled horn antenna by using multilevel fast multipole method (MLFMM), which provides fast computation to optimize antenna geometry by genetic algorithm (GA). Design results show that the proposed method provides an optimized geometry for an arbitrary mask pattern for a smooth walled horn geometry easily.**

***Index Terms* —Smooth walled horn antenna, multilevel fast multipole method(MLFMM), genetic algorism(GA), spline interpolation, optimization.**

1. Introduction

The primary radiator of reflector antenna designed for satellite communication and radio telescope requires the low sidelobe and low cross polarization. A corrugated horn antenna with these characteristics is heavy weight and complicated structure to fabricate corrugated wall inside [1].

To solve this problem, smooth walled horn structures were proposed [2-4]. This horn antenna is operated as multimodes by curve shape wall. Its length is shorter than multimode horn such as multi-flare horn generating high order modes, and light weight with simple structure.

It is necessary for multimode and curve shape in the modeling for its optimization. Mode matching method was applied to analyze the smooth walled horn antenna which requires to expand the fields by the summation of modes with difficulties to satisfy its boundary conditions [5]. This paper presents an easy numerical analysis for the optimization method for smooth walled horn antenna.

2. Proposed method

The flowchart of proposed method is shown Fig.1. The parameters of horn inner diameter are discretized by r_n and these ends are connected, which provides fast computation to optimize antenna geometry using the spline function to make the horn geometry with rotational symmetry as shown in Fig.2. This structure is analyzed by MLFMM to calculate radiation pattern and reflection characteristics. MLFMM drastically reduces analysis time and is easily applied to Genetic algorithm (GA) for horn geometry optimization. A cost function is given by the difference between a required radiation pattern and reflection characteristics. GA requires above flow repeatedly until the cost function becomes the minimum or exit condition is reached.

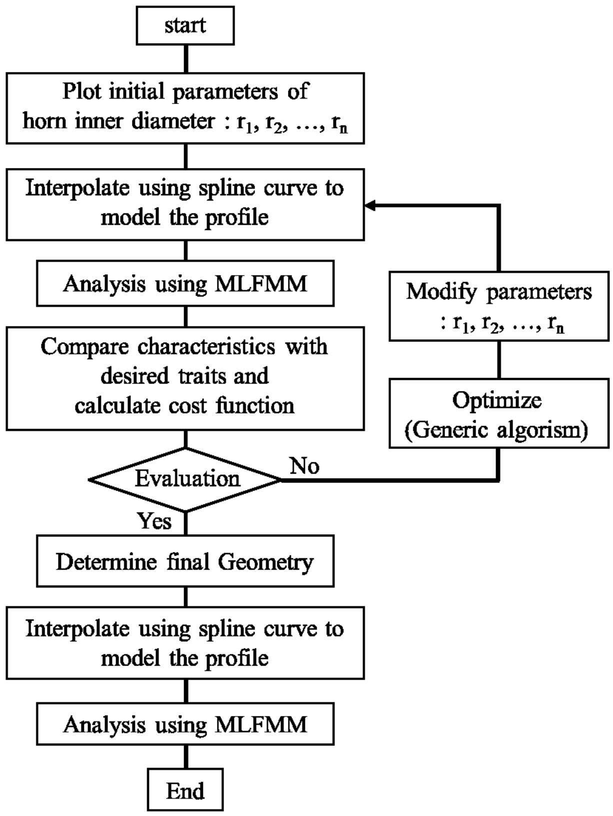

Fig. 1. Flowchart of proposed method

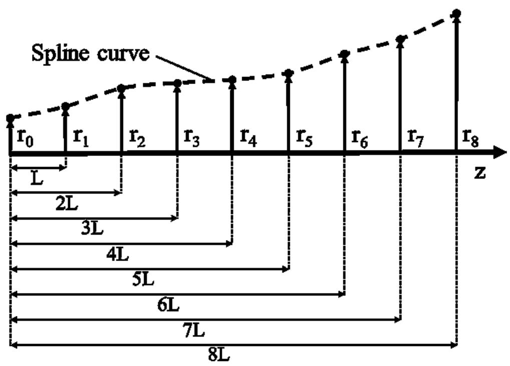

Fig. 2. Modeling method using spline curve

3. Comparison between MLFMM and MoM

In MLFMM, geometry is split in several boxes and each of them are calculated by MoM. That is why memory size and calculation time using MLFMM are materially shortened [6][7].

The memory size and the calculation time about a certain smooth walled horn is compared in MLFMM and MOM. The memory size and calculation time of MLFMM are 0.24 and 0.074 by normalizing MoM ones, respectively. Fig.3 shows that the radiation pattern of MLFMM is almost correspond with MoM, where mesh size is twelve meshes per wave length.

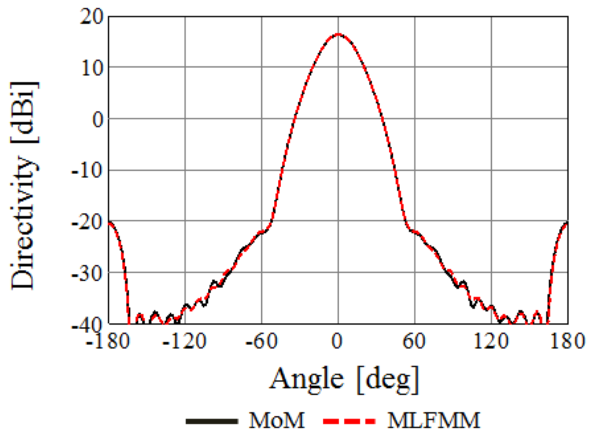

Fig. 3. Radiation patterns of MLFMM and MoM

4. Design result

We used the integral solver mode based on MLFMM of the electromagnetic field simulation software CST micro wave studio. GA was implemented using optimization function of this software. At the first step, the following goals were set; center frequency is 10 GHz, both E and H plane radiation pattern are below the mask pattern of $\cos^{10}\theta$ in the range from -45° to 45°, S_{11} is below -15 dB. To reach these goals, the mask pattern of $\cos^{10}\theta$ was formed and set as post processing. At this time, horn length was 150 mm, throat diameter was 23.8 mm, the number of parameter was 10 points.

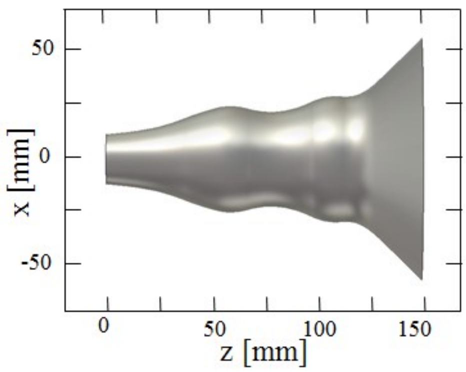

Fig. 4. Geometry of smooth walled horn antenna

Fig. 4 shows the optimal geometry of horn and Fig. 5 shows its radiation pattern. Both E-plane and H-plane pattern is within the intended mask pattern and cross polarization level is below -30 dB. This result shows that proposed method is easy numerical analysis for the optimization method for smooth walled horn antenna.

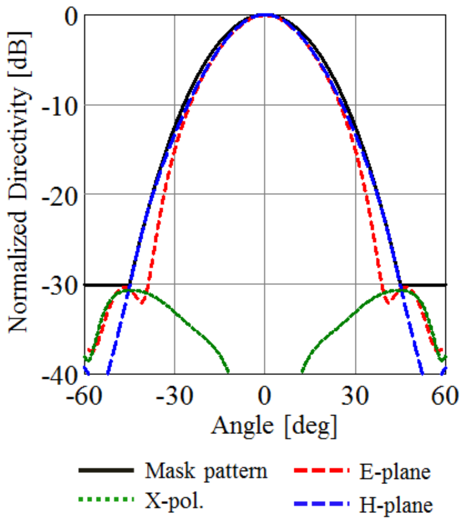

Fig. 5. Radiation pattern and mask pattern

5. Conclusion

This paper presents the analysis and optimization method of smooth walled horn antenna by using multilevel fast multipole method (MLFMM). MLFMM actualizes a faster analysis and enables the optimization using by genetic algorithm (GA). This proposed method doesn't require the complex formulation as previous study using mode matching method, so it enables to obtain intended geometry easily. The simulation result with CST software shows that it enables to optimize and obtain intended geometry easily using arbitrary mask pattern.

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