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Design of Pyramidal Horn Antenna at 10GHz Using WIPL-D Optimizer

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***Abstract*— Rectangular horn is one of the simplest and most widely used microwave antennas. In this paper, an electromagnetic simulator, WIPL-D is used to analyze and optimize the dimensions of the horn antenna which is based on the method of moments solution for computations. The standard horn antenna at 10 GHz is modeled and the radiation pattern is obtained. It is optimized to achieve more than 20dB gain using optimization techniques like genetic algorithm and simplex method. A comparison is made between these two optimization techniques with respect to number of iterations and time required for optimization. The radiation patterns of the optimized horn antenna are also observed. Geometry of the horn is modeled by exploring the 'symmetry' option. The amount of time, memory required, and size of EFIE matrix for both analyzed and optimized antennas are consolidated for entire, half symmetry, and quarter symmetry.**

***Keywords* — Horn Antenna, WIPL-D, Optimization, Genetic Algorithm.**

I. Introduction

The horn antenna is widely used as feed for large reflector and lens antennas, high gain element in phased arrays, and standard gain antenna in antenna measurements[1-2]. The accurate analysis of the horn antenna is based on the solution of integral equation by the moment method or finite difference time domain method [3-4]. An electromagnetic simulator which uses the method of moments technique for computations, WIPL-D pro is used for analysis and design of horn antenna at 10GHz.In WIPL-D, the electromagnetic modeling is of two parts: geometrical modeling and modeling of currents. In geometrical modeling, any arbitrary metallic structure can be considered as composed of appropriately interconnected plates and wires. In modeling of **c**urrents**,** the current along wires and over plates are approximated by polynomial expansions, whose basis functions automatically satisfy the continuity equations at the element junctions and free ends. Determination of unknown current expansion coefficients is based on the solution of (EFIE) electric field integral equation for current distribution [5-6]. By applying Galerkin method, the EFIE is transformed into a matrix system which is solved by using L U decomposition method [7].

The horn is excited by a wave guide which is fed by a coaxial cable and it is assumed that the antenna is made up of a perfect conductor; the plates of finite thickness are modeled as infinitesimally thin plates resulting in surface currents that represent the sum of interior and exterior antenna currents. Initially the geometry of a horn antenna with dimensions of aperture l_a = 2.66", l_b =1.95", length of the horn l_3 =5.46", dimensions of waveguide a=0.9", b=0.4", l=1.57" is modeled as shown in fig3. It is possible to use the symmetry feature in both electric and magnetic planes, so that only half or quarter of given antenna can be modeled. With these dimensions, the gain obtained is15.50dB.Near field is observed and the results of analysis for different models of antenna like with and without symmetry are tabulated.

The second part of the work is to optimize the dimensions of the aperture and length of horn to obtain the gain of 20dB. There are seven different optimization methods available with WIPL D pro optimizer [8]. Out of those, the most robust global optimization algorithm known to date, namely genetic algorithm is selected. It optimizes the project by simulating the Darwinian evolution principle. i.e. survival of the fittest. It is very useful for the optimization problems with many variables and huge optimization spaces .It needs many solver calls but is very likely to find the global minimum. The number of bits used per variables are 16, algorithm type is binary, cross over probability is 0.8, mutation probability is 0.2, total number of generations are 50, number of iterations are 80.

Another widely used optimization algorithm is simplex. This Nelder-mead simplex algorithm is a robust local optimization algorithm. If the starting optimization parameter values are in the vicinity of optimal solution, this algorithm is useful to find the best solution with very low probability of being trapped in other local optima. The constraints introduced on horn geometry by specifying lower and upper limits for the optimization parameters in both simplex as well as genetic. For l_a, the range given is 2.5"to 5".For l_b, it is from 2" to 5".For l_3 it is from 5" to 11".

II. Results

All computations presented here are performed on the Intel Core2duo@2.20Ghz. Fig.1 shows the 3D pattern of the simulated antenna. The resultant gain is 15.5dB. Fig.2 shows the near field pattern of the simulated antenna with field strength of 175.1 V/m.

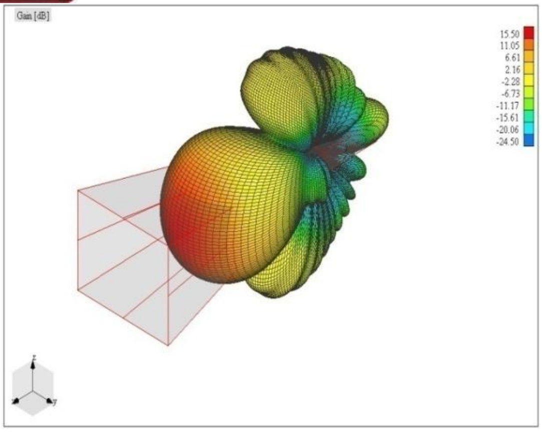

Fig.1. Radiation pattern of simulated horn antenna

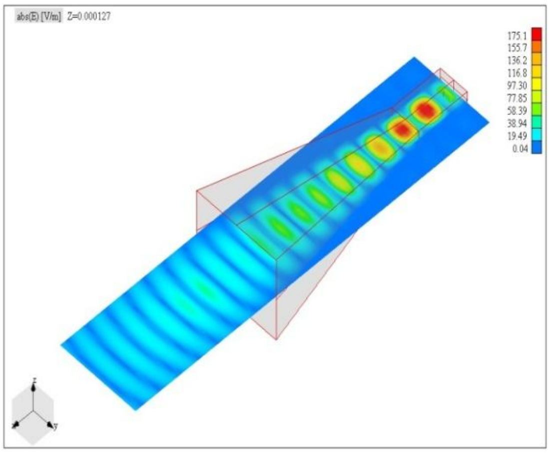

Fig.2. Near Field Radiation pattern

After specifying the optimization variables and running the genetic algorithm, optimizer displayed the difference between found solution and the criterion as 0.0, implies gain is exactly what is specified in the criterion for optimization i.e. 20dB.From the optimizer display, it is found that the time taken is 349sec and required solver runs are equal 49 to find the solution. Optimized dimensions are l_a=4.84”, l_b=4.4”, l_3=10.06”.The same procedure is repeated for simplex also. But simplex optimizer displayed the difference between found solution and the criterion is 0.68 and simulation lasted for 243 sec with 46 solver runs. Optimized dimensions are l_a=4.72”, l_b=4.51”, l_3=9.21”.It is evident that the simplex also leads to almost same solution but with more difference and less time compared to genetic algorithm.

Geometry of the simulated horn is shown in Fig.3.Model of the horn with optimized dimensions using genetic algorithm is shown in Fig.4. Radiation pattern for the optimized horn antenna in 3D is presented in Fig.5. The gain obtained is 20 dB .Near field pattern is also shown in Fig.6. Figs 7-10 represent different phi cut and theta cut polar and rectangular plots of simulated and optimized antennas overlaid on each other.Fig.11 shows the comparison of patterns for quarter, half and no symmetry for modeling the horn antenna. Table.1 consolidates analysis characteristics like the amount of time, memory required and size of EFIE matrix for both analyzed and optimized antennas.

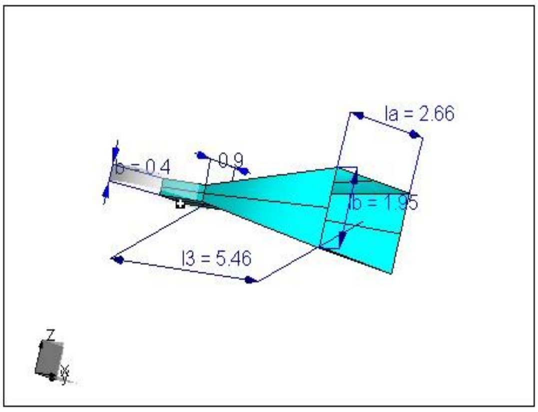

Fig .3. Geometry of simulated horn

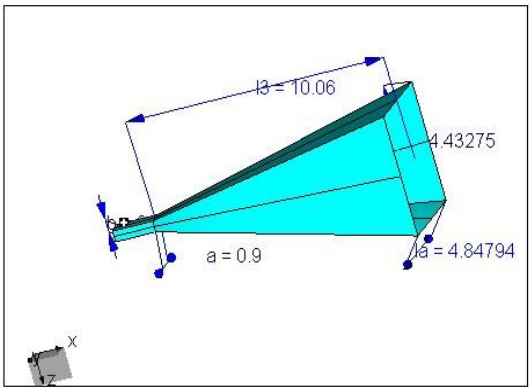

Fig.4. Horn with optimized dimensions

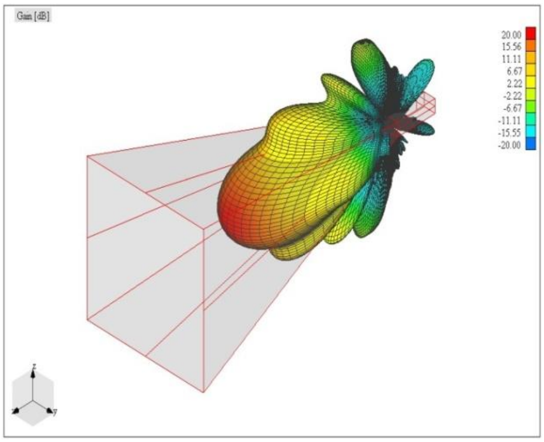

Fig.5. Horn with optimized dimensions

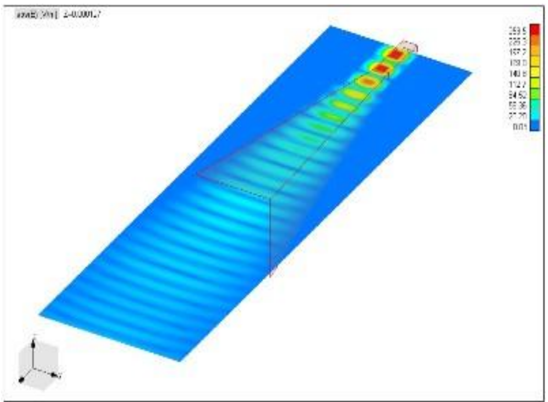

Fig.6.Radiation pattern of designed antenna

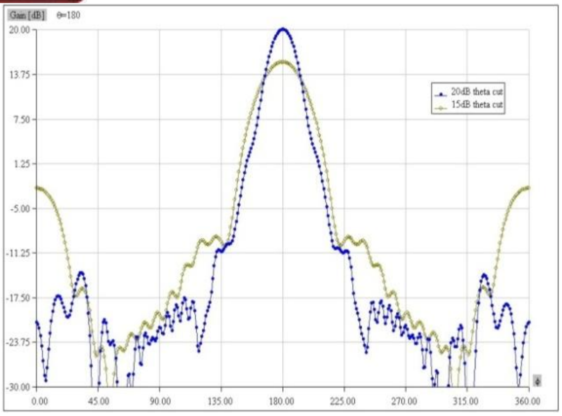

Fig.7. Theta cut rectangular plot

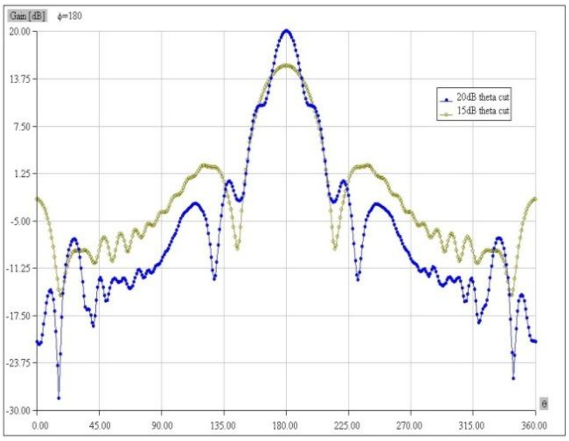

Fig.8. Phi cut rectangular plot

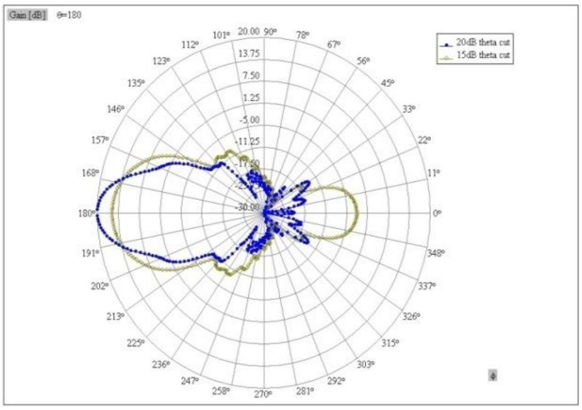

Fig.9. Theta cut polar plot

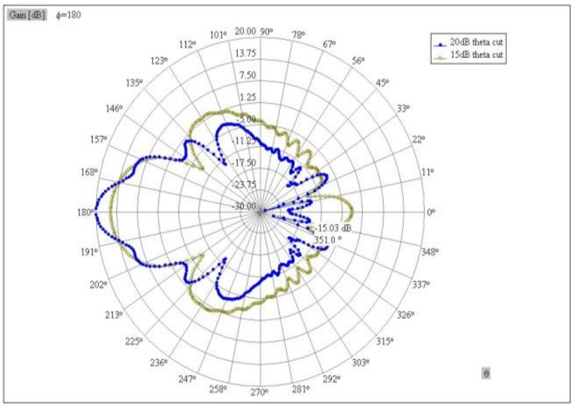

Fig.10. Phi cut polar plot

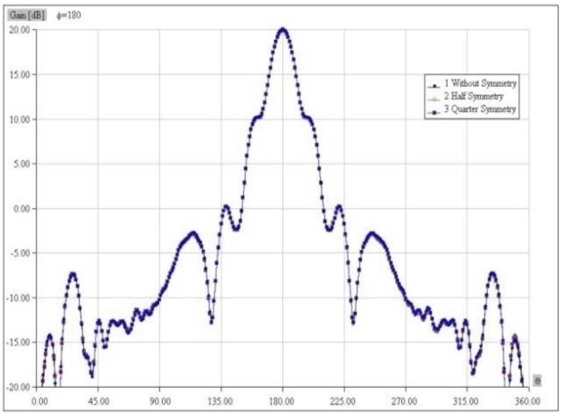

Fig.11. Comparison using symmetry options

Table 1: comparison of different characteristics

Horn Gain	Size of EFIE matrix	CPU TIME (sec)	Type Of Symmetry Used	Memory Required (MB)
20 dB	2835	158	Without Symmetry	61.3
	1394	126	Half	14.82
	717	121	Quarter	3.92
	717	38	Near Field	3.92
15 dB	1059	90	Without Symmetry	8.55
	518	88	Half	2.04
	273	85	Quarter	0.57
	273	18	Near Field	0.57

III. Conclusion

From Table 1, it is implied that for symmetry, the memory required, number of unknowns, or the size of EFIE matrix are drastically reduced. The time for evaluation is also considerably reduced. There is no difference in the radiation patterns obtained for no symmetry, half, and quarter symmetries. The gain obtained with the optimized dimensions of horn is exactly met with specified criterion using genetic algorithm. The same solution with little difference is also achieved with simplex algorithm but with a marginally less time and less number of solver runs. WIPL D pro is a useful tool for 3D and 2D analysis and design of different antenna structures in a limited time.

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