Design of Corrugated Absorbers for Oblique Incidence Using Genetic Algorithm

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Introduction

Genetic algorithm (GA) has been applied to the design of multi-layered planar and cylindrical absorber structures [1]. Corrugated coatings with non-planar shape profile offer an additional degree of design freedom and have been analyzed in [2]. In this paper, we apply GA to design the optimal shape for a corrugated coating under oblique incidence (see Fig. 1). To predict the performance of each shape, we employ a full-wave electromagnetic solver. GA with two-point crossover and geometrical filtering is implemented to achieve effective optimization. The optimized designs for different polarizations are presented.

GA Optimization

GA is implemented to optimize the shape of a corrugated absorber under oblique incidence. The absorber consists of a single layer of lossy material. It has one-dimensional periodicity along the x-dimension and is invariant along the z-dimension (Fig. 1). The incidence wave direction is defined by θ_{el} and $\phi_{grating}$. The elevation angle θ_{el} is measured from grazing while $\phi_{grating}$ is the azimuth angle measured from the z-axis. To encode each possible absorber shape into a chromosome, the height of the coating at each point along the x-direction is represent as a binary string. To achieve more realizable shape, we apply a sliding window filter that operates like a low-pass spatial filter during each generation of the GA. In addition, we enforce symmetry constraint on the shape.

To evaluate the performance of each absorber shape, we use a full-wave electromagnetic simulation code based on the boundary-integral formulation [2]. The design goal is to choose the coating profile that gives rise to the best absorbing characteristics over the frequency band of interest. The design frequency band is chosen to be from 8 GHz to 18 GHz, and the maximum height of the grating is restricted to 8mm. Associated with this design goal, we define the cost function as:

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$$Cost = \frac{1}{N}\sum_{n=1}^{N} Pn \ where \ Pn = \begin{cases} \Gamma(dB) + 20dB & if\ \Gamma(dB) \geq -20dB \\ 0 & if\ \Gamma(dB) < -20dB \end{cases} \quad (1)$$

Based on the cost function, the next generation is created by a reproduction process that involves crossover, mutation and sliding window filtering. A two-point crossover scheme involving three chromosomes is used. The process selects three chromosomes as parents and divides each chromosome into three parts. Intermingling the three parent chromosomes then makes three child chromosomes. The reproduction process is iterated until the cost function converges to a minimum value.

Results

Standard magram is used for the coating material. We consider the case when the incident angles are set to $\theta_{el}=30°$ and $\phi_{grating}=0°$. The bottom of the coating is backed by a conducting ground plane. The period of the profile is set to 2.032mm and is discretized into 32 points. The height of the groove at each point is described by a 6-bit number that ranges between 0 and 8mm (in 64 steps). First, we consider the case when only the VV reflection coefficient is used in the cost function definition. Fig. 2(a) shows the resulting GA-optimized shape, which closely resembles the triangular shape. Fig. 2(b) is plot of the simulated reflection coefficients (in dB) versus frequency for the optimized shape. We see that the reflection coefficient of the VV polarization nearly meets the -20 dB design goal over the entire frequency band from 8GHz to 18GHz. The HH polarization is not optimized and shows a much higher reflection coefficient. Next, we consider the reverse situation when only the HH reflection coefficient is used in the cost function. Fig. 3(a) shows the resulting GA-optimized shape. It is noted that the optimal shape of corrugation resembles a rectangular profile. Fig. 3(b) shows the simulated reflection coefficients (in dB) versus frequency for the optimized shape for both the VV and the HH polarization. The reflection coefficient of the HH polarization is less than –15 dB for nearly the entire frequency band of interest. In the third example, we optimize the shape by using the average of the reflection coefficients from the HH and VV polarizations in the cost function. The resulting shape is shown in Fig. 4(a). As we have seen from the last two examples, the design for the HH polarization is harder than that for the VV polarization. Therefore in this case, the cost is dominated by the HH consideration, and the resulting GA-optimized shape is not that different from the optimized shape for the HH-polarization shown in Fig. 3(a). As a final example, we impose an additional constraint such that the complementary air region has the same shape as the absorber. Presumably, this means we can make two usable pieces of absorber by cutting them from a single thick piece. The optimized shape and the reflection coefficient are presented in Figs. 5(a) and 5(b), respectively.

Conclusion

GA-optimized shapes for a corrugated absorber under oblique incidence have been presented for different incident polarizations. The designed absorber shape for the VV polarization closely resembles a triangular profile, while that for the HH polarization resembles a rectangular profile. An optimized absorber profile with an additional complementary constraint to achieve a more efficient material usage is also reported.

Acknowledgments
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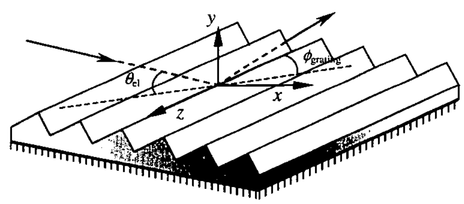

Fig. 1 Geometry of the corrugated absorber.

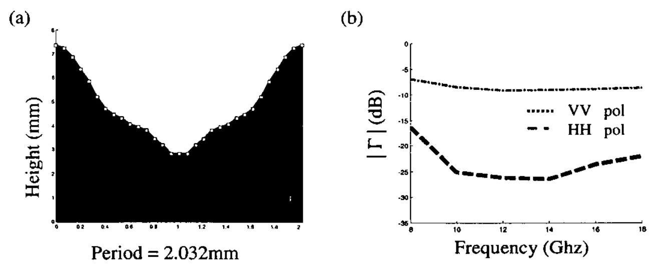

Fig. 2 (a) GA optimized shape for the VV pol. (b) Reflection coefficient (dB) versus frequency

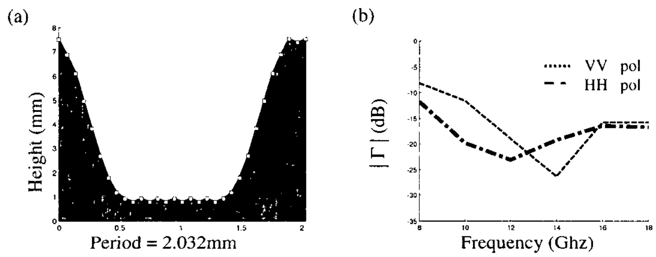

Fig. 3 (a) GA optimized shape for the HH pol. (b) Reflection coefficient (dB) versus frequency

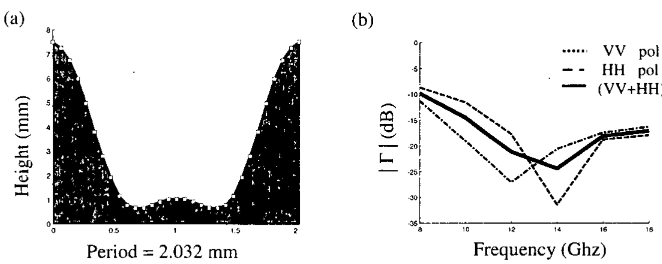

Fig. 4 (a) GA optimized shape for the average of VV and HH pol. (b) Reflection coefficient (dB) versus frequency

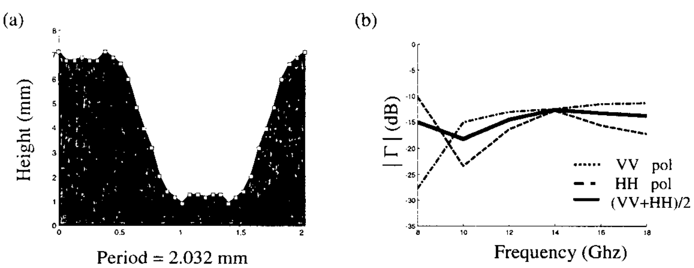

Fig. 5 (a) GA optimized shape with the complementary constraint. (b) Reflection coefficient (dB) versus frequency