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Frequency selective surface structure optimized by genetic algorithm*

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Frequency selective surface (FSS) is a two-dimensional periodic structure which has prominent characteristics of bandpass or bandblock when interacting with electromagnetic waves. In this paper, the thickness, the dielectric constant, the element graph and the arrangement periodicity of an FSS medium are investigated by Genetic Algorithm (GA) when an electromagnetic wave is incident on the FSS at a wide angle, and an optimized FSS structure and transmission characteristics are obtained. The results show that the optimized structure has better stability in relation to incident angle of electromagnetic wave and preserves the stability of centre frequency even at an incident angle as large as 80°, thereby laying the foundation for the application of FSS to curved surfaces at wide angles.

Keywords: frequency selective surface (FSS), genetic algorithm (GA), optimization
PACC: 7300, 7360

1. Introduction

Research on frequency selective surface (FSS) began between the late 60s and the early 70s,[1] while the periodic electromagnetic band-gap structure has been investigated increasingly.[2−4]

Research on FSS began in China in the 1990s, concentrating mainly on the application of bandpass FSS to radome.[5,6] Now the study is involved with the application of the FSS to wave absorption and antenna technology,[7−9] but the study on application of FSS to stealth radome is always a hot subject. How to keep the transmission characteristics of FSS structure stable at a wide incident angle of electromagnetic wave is the key point and it is also the main problem which influences the application of FSS to curved surfaces. Recently, starting from the composition form of FSS element the problem has been theoretically studied by using a spectral domain method, giving out relatively stable element forms when the incident angle of electromagnetic wave is changed. The significant results have been obtained.[10,11] FSS transmission characteristic is a function of polarization mode and incident angle of incident electromagnetic wave, geometric shape and arrangement mode of element, and electric parameters of medium substrate, and so it is easily influenced by changing any of these factors.[12] This multiparameter optimization brings about a great difficulty in designing and it is also the reason why it is hard to apply the FSS to curved surfaces in practice. In the previous researches, both theoretical and experimental, more efforts have been made to ascertain the influence of individual factors, such as medium substrate, element arrangement cycle, etc., on FSS characteristics,[13,14] however the integral optimum design research on the factors which influence the FSS structure transmission characteristics has not been carried out. In the present paper, starting from the angle of optimization design, studied are the FSS structure at wide incident angles of electromagnetic wave and the influence of element form, thickness of medium, etc. by using genetic algorithm (GA).[15,16] A structure in which FSS centre frequency does not change with incident angle of electromagnetic wave has been obtained, thereby laying the foundation for the application of FSS to curved surface.

2. Genetic algorithm

In the GA, the biological evolution steps are simulated by taking biological evolution process as the background, and the concepts of propagation, hybridization, variation, competition and selection are introduced. By acquiring a group of feasible solutions and recombining the feasible solutions, their

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shifting tracks or tendencies towards optimum solution in multi-dimensional space are improved by using the GA. It is a global optimization algorithm which overcomes the shortcoming of traditional optimized method, i.e. easily falling into local extreme value. The GA principle is to express the solution as 'chromosome', i.e. the strings in binary code, and to give out a group of 'chromosomes', i.e. assumption solution before executing optimized algorithm. Then, these assumption solutions are substituted into 'environment' of questions while 'chromosomes' which adapt themselves to the environment are selected and copied following the survival-of-the-fittest principle. Further, by means of crossing, the variation process generates new 'chromosome' which adapts itself to the environment better. Eventually, following these evolutions, a 'chromosome' which adapts itself to the environment best appears, i.e. the optimal solution of the problem is obtained. Figure 1 is GA basic flowchart.

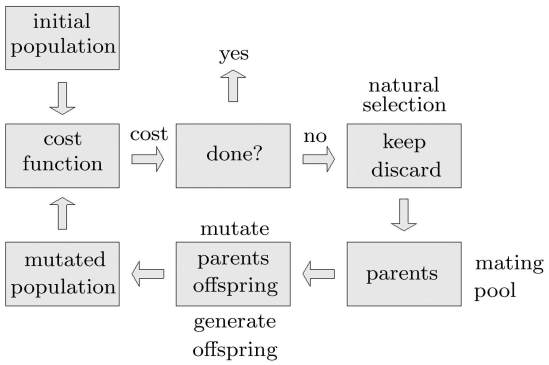


Fig.1. Genetic algorithm flowchart.

3. Optimization and result of GA

FSS structure is designed by layers, i.e. in the form of medium 1- FSS screen-medium 2, as shown in Fig.2. The dielectric constant of medium 1 equals that of medium 2. In the present paper, the thickness and the dielectric constant of the mediums which constitute the FSS, the graph and the periodic arrangement of the elements are optimized by using the GA. The optimized initial group value is 20. The initial value of the medium thickness ranges from 1.55 to 2.0 mm, specifically, it is 1.5 mm; the initial value of the dielectric constant is between 3.0 and 3.3, or rather 3.0; the incident angle of the electromagnetic wave is 10° initially, and its maximum value is 80°; each step length is 10°, at which a TE polarization wave is incident; the centre frequency of FSS structure is 6 GHz.

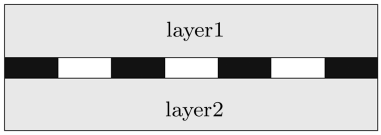


Fig.2. FSS structure.

3.1. Optimized result of medium electric parameter and element periodicity

Optimized dielectric constant is 3.1; the thicknesses $d_1 = 1.79$ mm and $d_2 = 1.57$ mm are adopted; initial optimization and elements are arranged in square. Then only the periodic values are optimized and the period ranges from 9 to 10 mm. The optimized period is $T_x = T_y = 9.81$ mm as shown in Fig.3.

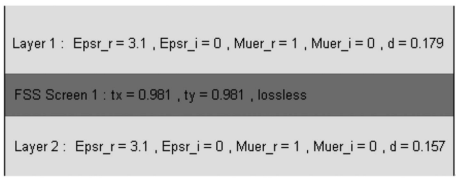


Fig.3. FSS mediums and element periodic parameters.

3.2. Elements

The elements are shown in Fig.4. The elements are optimized by using the method in which the GA graph is generated programmatically instead of the normal way of optimizing element graph dimension. The element dimension is 32×32. The black area shows the metal conductor and the white area represents the aperture in Fig.4.

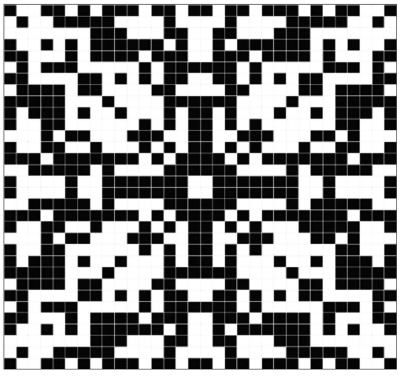


Fig.4. Optimized FSS element graph.

3.3. Transmission characteristics

In Fig.5, the elements are in square ($T_x = T_y = 9.81$ mm) pitch arrangement, with the optimized

medium taken as substrates and covering layers. The characteristic curves of power transmission coefficient for different incident angles of electromagnetic wave are shown in Fig.5 where the abscissa axis represents the frequency and the ordinate axis refers to the power transmission coefficient. Obviously, optimized FSS structure is steady in performance with keeping the centre frequency at 6 GHz just the same as that for the normal element of FSS. The Q value (quality factor) of FSS structure increases as incident angle of electromagnetic wave increases.

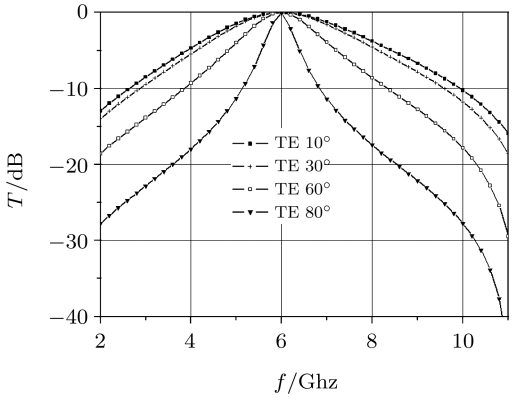


Fig.5. Transmission characteristics for different incident angles of electromagnetic wave.

4. Conclusions

FSS is mostly applied to curved surfaces. For example, it can serve the function of stealth of radar wave when used in Radom, but the sensitivity of FSS transmission characteristics to incident angle of electromagnetic wave restricts the application of FSS to curved surfaces. Although many researches are already done in this aspect, none of them are carried out from the angle of integral optimization. In the present paper, based on the application of FSS to electromagnetic wave incident at wide angles, FSS structure parameters are optimized by using the GA, then the corresponding optimized results and transmission characteristics are given out. The centre frequency of the optimized FSS structure keeps stable at wide incident angles of electromagnetic wave, even preserves the stability at an incident angle as large as 80° which lays the foundation for the application of FSS to curved surfaces in wide angles.

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