Design of dual-band reflectarray using genetic algorithm

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Abstract - **This paper proposes novel design method of dual-band reflectarray using genetic algorithm (GA). Ordinary, each elements of reflectarray are designed to have desired reflection phase. However, when we adopt same polarization in dual frequencies, the element configuration designed to satisfy desired reflection phase in one frequency influences the characteristics in other frequency. Therefore, it is difficult to achieve dual-band reflectarray. To address the issues, we adopt two layer patches for element to increase flexibility of design and optimize the patches configuration using GA. As a result, we achieve novel reflectarray that reflect wave towards the direction of theta equal to 27 deg.**

Index Terms — **Reflectarray; Dual frequency; Multi-band; Genetic algorithm; 5G; M2M.**

1.   Introduction

Recently, high frequency exceed 5 GHz is considered to use for fifth- generation (5G) wireless systems or near field radio communication to achieve super high speed and broad band mobile communications [1], [2]. The coverage area however, becomes smaller when using a high frequency because the propagation loss increases due to diffraction, and this leads to difficulty in using high frequencies in mobile communications. Moreover, the Machine-to-Machine (M2M) market is growing rapidly [3]. When wireless access is applied to the communication between machines, bad propagation environment, e.g., niche space between buildings or home furnishings, etc., needs to be overcome by appropriate technology. We have proposed to use reflectarrays for improving the propagation performance, by eliminating blind areas, a significant problem at frequencies much higher than microwaves [4]. Recent mobile terminal equipment uses multi-band frequency for cellular, Bluetooth, WiFi, etc. Therefore multi-band reflectarray also required. The dual frequency reflectarray that uses horizontal polarization for one frequency and uses vertical polarization for the other frequency is reported [5], [6]. However, it is difficult to achieve dual frequency reflectarray that uses same polarization in two frequencies. Because, generally, when same polarizations are used, modifications of the element structure or size influence both two frequencies and it is also difficult to design the element structure in two frequencies independently. There are some reports to use GA for reflectarray design [7] To address the issues, this paper proposes to use genetic algorithm (GA) [8] and design

reflection phases from array element satisfy desired reflection phase in two frequencies.

2.   GA Analysis model for dual requency reflectarray

The analysis models using genetic algorithm (GA) for dual frequency reflectarray are shown in Fig.1. Fig.1 (a) shows oblique perspective figure and Fig. (b) shows top view (XY-plane). This paper adopts two layers patches to keep flexibility for design to determine dual frequency reflection phases independently. Fig. 1 shows the analysis model for array elements of which reflectarray consists. Each patch is designed using GA shown in Fig.1 (b). Each patch is divided n by n meshes. The existence and absence of metal patch in each mesh is represented by 0 and 1 of the gene respectively. The reflection phase is analyzed using FDTD method when plane wave is given from z axis positive direction. Periodic boundary conditions are used. The cost function (evaluate function) $h(x)$ of GA is shown in equation (1). In the equation (1) ϕ_{df_i} is desired reflection phase at frequency f_i and ϕ_{f_i} is calculated reflection phase at frequency f_i

$$h(x) = \sum_{i=1}^{n} w_i g_i(x) = \sum_{i=1}^{n} w_i \left(500 - \left|\phi_{f_i} - \overline{\phi_{df_i}}\right|\right) \dots (1)$$

Dual frequency reflectarray that can reflect same desired direction in two frequencies is designed. The design conditions are shown in Table 1. Phase difference $\Delta \phi_{fi}$ of each element are calculated using equation (2) when operating frequency f_i , reflection angle α and element spacing Δd are given shown in table1. $\sin(\alpha) = (\lambda \Delta \phi_{f_i} / 2\pi \Delta d) \dots (2)$

GA chromosome consists of 32 genes when element division numbers of both layer 1 and layer 2 are 4. The combinations of reflection phase are 8 shown in Table 2 when phase differences are set 90 deg. and 135 deg. at 1.0 GHz and 1.5 GHz respectively.
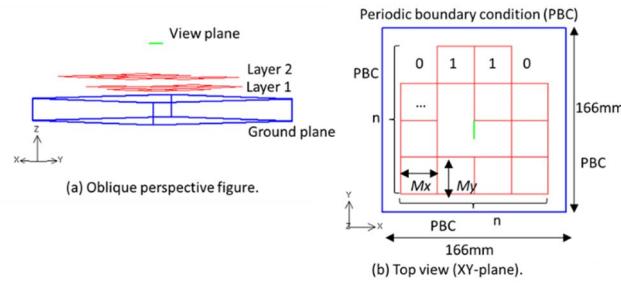

Fig.1Reflection phase analysis model using GA.

Element structures designed using GA are shown in Fig.2. In Fig. 2, black, white and gray patches shown that exists in

layer 1, layer 2 and both layer 1 and 2, respectively. The reflectarray for dual frequency constructed using these elements is shown in Fig.2. Figure 2 shows one period of reflectarray. The radar scattering cross sections of dual frequency reflectarray are calculated using FDTD method with periodic boundary conditions are shown in Fig.3 with both two frequencies. The final dual frequency reflectarray achieved desired reflect wave direction that is – 27 deg. in both 1.0 GHz and 1.5 GHz.

3. Conclusion

This paper proposed novel design method of dual-band reflectarray using genetic algorithm (GA). Ordinary, each elements of reflectarray are designed to have desired reflection phase. However, when we adopt same polarization in dual frequencies, the element configuration designed to satisfy desired reflection phase in one frequency influences the characteristics in other frequency. Therefore, it is difficult to achieve dual-band reflectarray. To address the issues, this paper adopted two layer patches for element to increase flexibility of design and optimize the patches configuration using GA. As a result, novel dual band reflectarray is achieved. The reflectarray can toward reflect wave the direction of theta is equal to 27 deg. and phi is equal to 0 deg. in dual frequency when incidence wave is coming from the direction of theta equal to 0 deg. and phi equal to 0 deg. in dual frequency.

Symposium on Antennas and Propagation (ISAP) Proceedings. Thank you for your contribution to ISAP 2016.

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TABLE (1). Design conditions and parameter

Factor	Symbol	Unit	Value	
			f_1	f_2
Operating frequency	f_i	GHz	1.0	1.5
Reflection angle	α	Deg.	-27	-27
Element spacing	Δd	mm	166	166
Element spacing	Δd	λ	0.55	0.83
Phase difference	$\Delta \phi_{fi}$	Deg.	90	135
Element division number	n		4	4
Mesh size x	Mx	λ	0.138	0.207
Mesh size y	My	λ	0.138	0.207

TABLE (2). Combinations of reflection phase

	Unit	#1	#2	#3	#4	#5	#6	#7	#8
Reflection phase at f_1	Deg.	0	90	180	270	0	90	180	270
Reflection phase at f_2	Deg.	0	135	270	45	180	315	90	225

Element structures designed using GA

■ : Layer 1, ▩ : Layer 1 & layer 2, □ : Layer 2
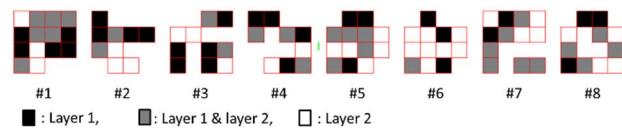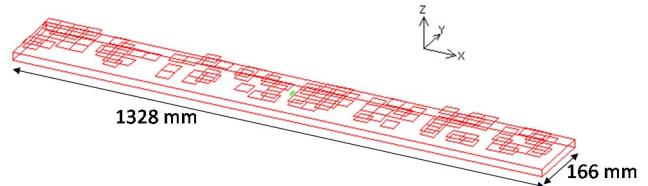
Fig.2 Reflectarray structure for dual frequency designed using GA (One period).
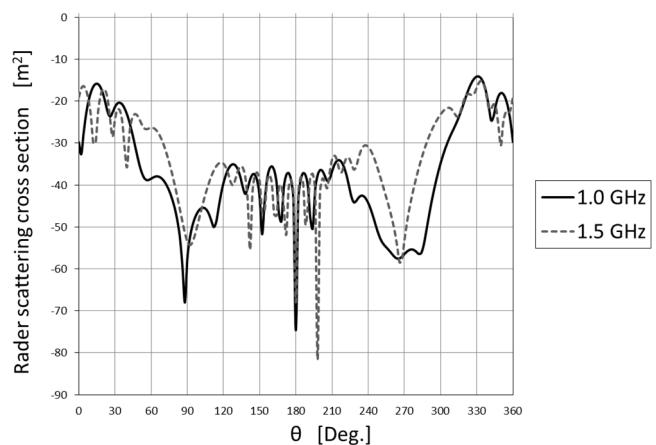
Fig.3 Radar scattering cross section of dual frequency reflectarray.