# Reflectarray with arbitrarily shaped elements for linear-to-circular polarization

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***Abstract* – This paper proposes arbitrary shaped elements for linear-to-circular polarizer for reflectarray. We optimized the resonant elements with orthogonal two axial symmetry by the genetic algorithm(GA). Moreover, the effectiveness of the proposed elements is verified by discussing radiation characteristics of a fabricated offset reflectarray numerically and experimentally.**

***Index Terms* — reflectarray, genetic algorithm, arbitrary shape.**

## 1. Introduction

Microstrip reflectarrays are required that the resonant elements provide an arbitrary phase value in the range of 360 degrees. It's also desirable that the elements have dual-polarization and/or low cross-polarization properties. Such properties have been obtained by using some elements; convex elements[1], omega shaped resonant elements[2], and four axial symmetry elements[3][4]. In this paper, we propose resonant elements for linear-to-circular polarizer with orthogonal two axial symmetry optimized by the genetic algorithm. By keeping reflection phase difference between the TE and the TM incidences 90 degrees, linearly polarized orthogonal waves will be transformed into a circularly polarized wave. Furthermore, in linear polarizer use, these elements have a low-cross polarization property because of their symmetric structure.

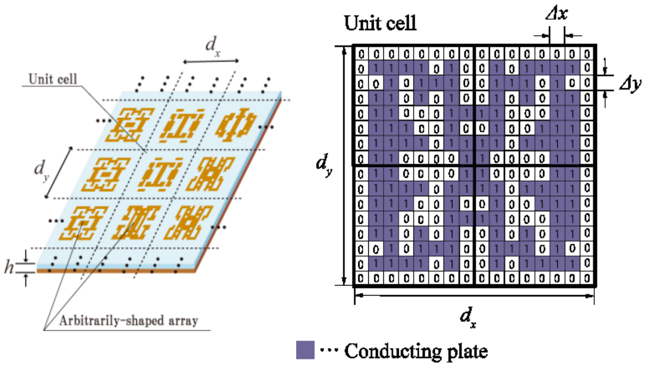
## 2. Design Method

Fig. 1(a) shows a reflectarray with arbitrarily shaped microstrip elements. The reflection phase property of each element is analyzed by the method of moment based on the spectral domain imposing the periodic boundary condition.

The element configuration in the GA design are depicted by expressing it with "1" when a conductor exists on a sub-cell, otherwise with "0", as shown in Fig. 1(b). As seen in Fig. 1(b), the resonant element of a unit-cell has orthogonal two symmetric structure. Then we optimize an element configuration by carrying out choice, crossing-over and mutation in the GA. We use the following fitness function

$$Fitness = \sum_i F_{TE}(f_i) + \sum_i F_{TM}(f_i) \qquad (1)$$

where $F_{TE}(f_i)$ and $F_{TM}(f_i)$ are evaluation values at the i-th frequency, for the TE and the TM incidences respectively. If difference between the ideal and the calculated reflection phase is less than α, these values equal 0. Otherwise difference is more than α, these values equal phase difference in its entirety. Thus the α is the allowance value which is determined by evaluating the antenna gain loss due to phase error. Ideal phase value is specified in the TE incidence, while ideal phase value in the TM incidence is automatically determined by adding 90 degrees to a calculated phase value for the TE incidence.



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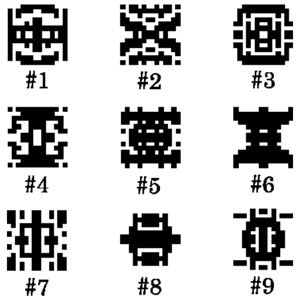
(a) Structure. (b) Configuration of element.

Fig.1. Reflectarray with arbitrarily shaped elements.

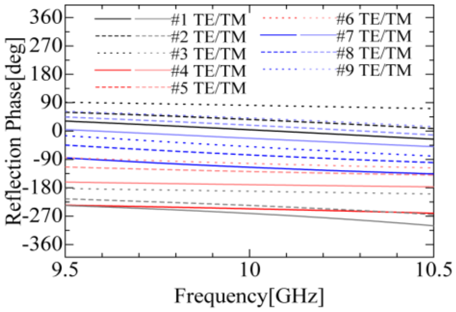
## 3. Arbitrarily Shaped Elements

We optimize linear-to-circular polarizer elements by the fitting function under the conditions of the incident angle 30 degrees, the frequency $f_0$ = 10 GHz, and the bandwidth from 9.5 GHz to 10.5 GHz. The dimension of each element $d_x$ and $d_y$ are 12 mm respectively and the thickness of the substrate is 3.0 mm. The unit-cell is divided into 16×16. The number of elements is 9, corresponding to 40-degree interval and α = 10° is adopted, so that the degradation from the ideal gain is about 0.35 dB.

Fig. 2(a) shows geometry of the elements obtained by optimization, and Fig. 2(b) shows their reflection phase properties. Fig. 3(a) shows reflection phase difference between the TE and the TM incidences. Fig. 3(b) shows the axial ratio for each element. We can see from these figures that the reflection phase difference is about 90 degrees and the axial ratio is less than 1.5.

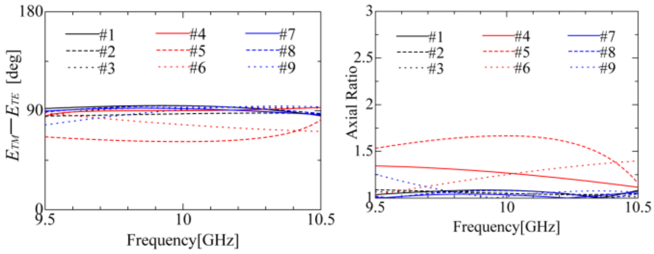


(a) Geometry of designed elements.



(b) Reflection phase property.

Fig. 2. Designed result and these phase properties.



(a) Phase difference between the TE and the TM incidence.

(b) Axial ratio.

Fig. 3. Evaluation of frequency characteristic for periodic structure.

## 4. Designed Reflectarray

Using optimized elements, we design an offset feed reflectarray. Fig. 4(a) shows the arrangement of the antenna, and Fig. 4(b) shows the photograph of the fabricated reflectarray. Measured and calculated radiation patterns for linear polarized orthogonal waves are shown in Fig. 5(a). The cross-polarization level is suppressed to less than -35 dB. Fig. 5(b) shows the circular radiation pattern. The peak levels of the cross-polarization component are less than -20dB.

## 5. Conclusion

We have proposed the resonant elements which transform orthogonal waves into the circular polarized wave. Their effectiveness has been verified through numerical and experimental discussions.

## Acknowledgment

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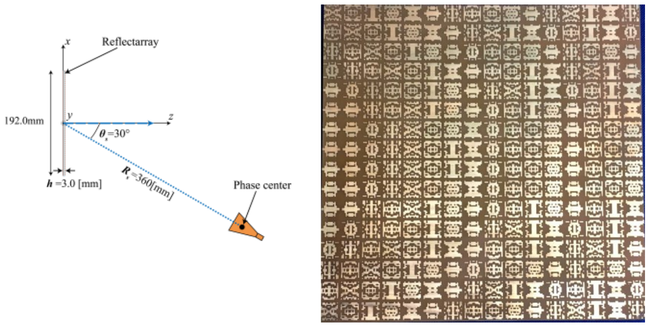
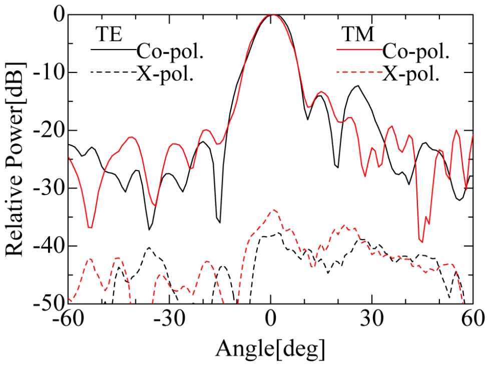
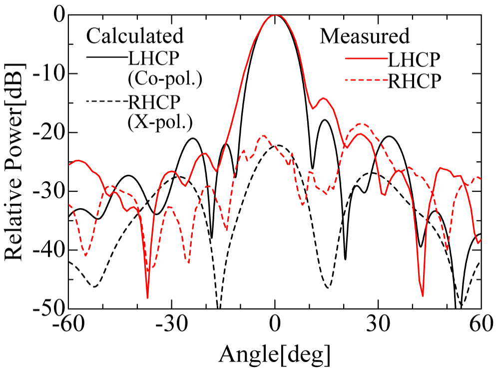


(a)Antenna configuration. (b)Fabricated reflectarray.

Fig. 4. Designed reflectarray antenna.



(a)Linearly polarized wave.



(b)Circularly polarized wave.

Fig. 5. Comparison of calculated and measured radiation patterns.

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