A Double-layer Transmitarray Element Based on Complementary FSS Structure

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***Abstract*—In this paper, a novel transmitarray element is reported for millimeter wave applications. Novel double-layer FSS structure is designed for simplicity purpose. To augment the element's transmission performance, complementary structure element are proposed by combining patch and slot type element together. With this novel configuration, the phase compensation range of new transmitarray element is improved significantly, compared with other FSS designs. The element performance are simulated by a full-wave commercial software. The numerical results demonstrate a satisfactory performance for a low-cost high-performance transmitarray element design at 60 GHz.**

***Keywords*: Antenna, transmitarray, complementary struture, millimeter wave.**

I. INTRODUCTION

Transmitarray antennas are evolved from lens antenna. It has a planar structure with a feed behind the radiation aperture, combining the features of microstrip and lens antennas such as low-profile, easy-integration and reduction of feed blockage effects. These characteristics make transmitarray a research hotspot at antenna area in recent years. However, traditional transmitarray elements [1]–[3] have to adopt at least a 3-layer structure to obtain enough phase compensation range for better performance, the multilayer design also results in complicated structure and high cost, that further restrict its future applications. Recently, a double-layer transmitarray element is presented in [4], vias are introduced to augment double-layer element's performance. Due to the limitation of fabrication technology, the vias are too large for millimeter-wave element design.

This paper presents a novel low-cost element for millimeter wave transmitarray antennas. In order to achieve a simple structure, a double-layer complementary element is proposed by combining patch and slot-type structure together. The proposed complementary structure is introduced and its phase compensation mechanisms are analyzed.

II. TWO-LAYER TRANSMITARRAY ELEMENT

The Transmitarray has been studied for years. The main concern is its relatively complex structure for satisfactory performance. The relationship between the layers and element performance (phase and magnitude) has been revealed in [5] with the conclusion that it is almost impossible to build a double-layer FSS element to fulfill the requirement of both phase and magnitude. Some novel FSS designs are desired to break through the limit for better performance with double-layer structure.

Fig. 1. Evolution of proposed element structure: (a) patch; (b) slot type; (c) total structure.

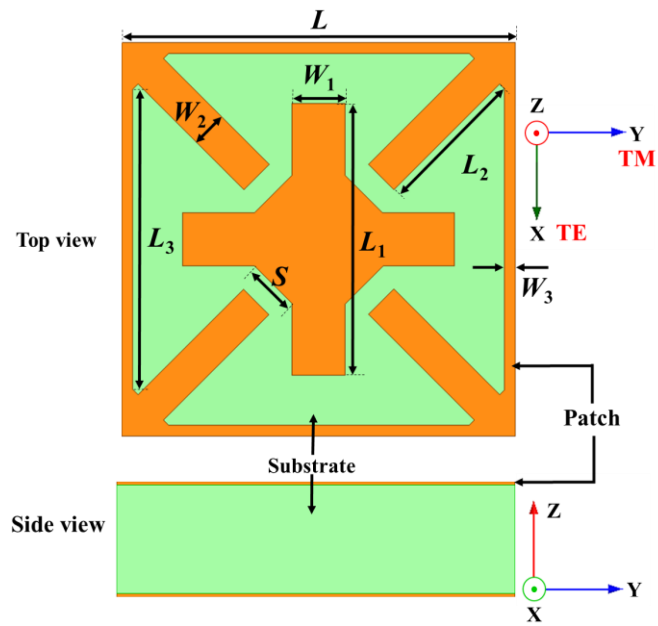


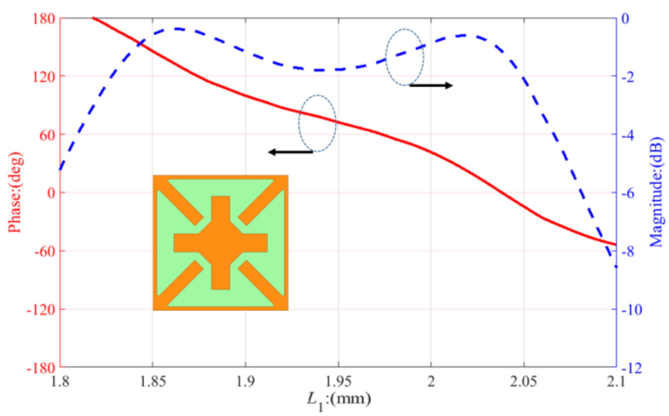
Fig. 2. Structure of the proposed element: (a) top view; (b) side view.

The evolution structure of the proposed complementary transmitarray element is shown in Fig. 1. Slot-type structure and cross patch element are put together into an element. The slot type element is modified from a reflectarray element [6]. It has four stubs connected to the frame at the side, while the cross patch is placed at the center. By synthesizing two type of structures into one, a new transmitarray structure is achieved.

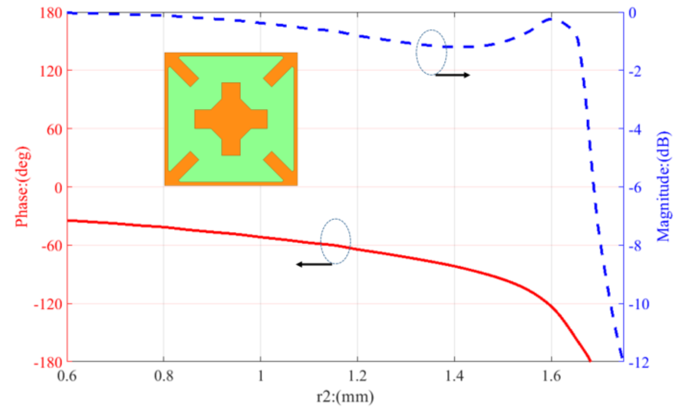
The transmitarray element is designed for millimeter wave at 60 GHz. The unit-cell periodicity is set to be 2.75 mm × 2.75 mm (~0.6 wavelength at 60 GHz) while the thickness of substrate is set as 0.508 mm with a relative dielectric constant of 2.2. The patch and slot structures are printed at both side of the substrate with identical size. The cross patch element has a length and width of L_1 and W_1 (0.37 mm), respectively. The frame at the side has a width of W_3 (0.075 mm), four stubs with the length and width of L_2 and W_2 (0.25 mm) are connected to the corners.

As the proposed element has many different parameters, it provides a large freedom to obtain satisfactory element performance. Two configurations are proposed for this new element with simulation results. For configuration 1: the length of stub is fixed and set as 1.045 mm and the parameter S is 0.375 mm. The cross length varied from 1.8 to 2.1 mm. With these parameters, this element has achieved a phase range from 167 ~ −10° and the magnitude is above −1.8 dB. For configuration 2: the length of stub L_2 and the parameter S are both varies with the cross length from 0.6 to 1.7 mm. The relationship between L_1 and L_2 is L_2 =0.1mm+(L_1−0.5mm)/2; the parameter of S has a fixed proportion of 0.147 of the cross length. The corresponding phase rang is from −35 ~ −165° with the transmission magnitude above −1.2 dB. With these two configurations, this element has realized total phase range ~ 310° and the magnitude is above −1.8 dB. With the manipulation of different parameters, a satisfactory element performance can be achieved.

It seems that element with configuration 2 has similar phase and magnitude performance compared with other double-layer element. The difference is resulted from configuration 1, in which there is a small gap between cross patch and four stubs. Due to the coupling the gap, the current energy is distributed at both structures and the transmission phase can be modified by tuning the gap structure.



(a)



(b)

Fig. 3. Element performances with two different configurations: (a) configuration 1, (b) configuration 2.

III. Conclusion

A novel double-layer transmitarray antenna is presented for millimeter wave application in this paper. The simulated results of proposed element has a compensation phase range of ~310° with magnitude better than −1.8 dB. This double-layer FSS element has exceed the limit in [5] with satisfactory performance. It opens an new horizon for the design of high performance transmitarray antenna, which effectively reduces the structure complexity.

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