A transmissive metasurface based on active amplifier for amplitude manipulation

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Abstract- A transmissive coding metasurface based on active power amplifiers is presented here, for space energy modulation. By integrating RF amplifying transistors into metamaterial structure, we realize a coding metasurface, to modulate the amplitude of transmissive wave. Because of the excellent amplification and isolation of RF amplifying transistor, the presented metasurface can not only realize power amplifying, but also achieve power reduction. The working frequency of the designed metasurface is set at 5 GHz. The measured results show good agreement with the simulations, validating our idea.

I. INTRODUCTION

Metasurfaces are two-dimension version of metamaterials, showing good performance on the control of electromagnetic (EM) wave. Both phase and amplitude responses can be manipulated by metasurface with specific structure. Comparing to the three-dimension metamaterials, metasurfaces not only yield low profile, but also has lower cost and easy-fabrication. Due to these advantages, various researches are performed on the topic of metasurfaces, like planar lens antenna [1], perfect absorber [2], and imagings [3].

The generalized Snell’s law is proposed in 2011 [4], bringing with new perspectives of metasurfaces. On the basis of it, the concept of coding metasurfaces is introduced by Cui [5], which opens up a new direction for metasurface design. Based on this perspective, the physical material is first connected with digital information concept (0/1 coding), realizing digital design on traditional metamaterials. This method greatly simplifies the design process of metasurfaces, and various applications based on coding metasurfaces are realized: imaging [6] and vortex beams [7].

In various manipulation methods of metasurfaces, amplitude control is one of the important means. For passive metasurfaces, the special structure for incidence can realize absorption [8, 9]. However, these passive metasurfaces can only reduce the incident power, which is quite limited. To address this defect, we propose an active metasurface based on power amplifier (PA), to not only realize power reduction, but also power amplification. The proposed metasurface is designed as a transmissive form for linear incidence at 5 GHz. The measured results show good agreement with our design.

II. RESULTS

A. Element design

The designed element structure of transmissive metasurface is provided in Figure 1 (a). The element is composed of three layers, which are F4B, metal layer and F4B, as well as the related metal structure on the top and bottom of F4B. The dimension of these two circular patch mainly determined the working frequency. The circular metal structure on the top and bottom layers are connected by the metal line, which can be almost regarded as microstrip line, on which the PA is placed to amplifying the transmission power. And the metal lines on the top and bottom layers are connected by a via hole, to transmit EM power from the front to the back. The detailed dimensions listed in Figure 1 (a) are provided as following: R=10.8 mm, a=40 mm, h=1 mm.

Figure 1. (a) The structure of designed metasurface element. (b) The designed circuit of PA on the element.
The designed circuit of PA is listed in Figure 1(b), the values of these circuit components are given as following: C1=18 nF, C2=1 nF, C3=1 μF, C4=56 pF, C5=56 pF, L1=39 nH, R1=24 Ω. To reduce the interaction from these components to spatial EM wave, the packaging and arrangement is designed as compact as possible. We apply a commercial transistor from Qorvo (TQP360180), as the PA in our design. Please note that this PA can work from 0 to 6 GHz. Since our metasurface structure is designed at 5 GHz, this PA meets our requirement. The PAs on the top and bottom layers are placed into the same direction, according to the consistent power transmission direction.

B. PA Experiments

To validate our idea, we first test the performance of a single PA, as showed in Figure 2(a), the arrangement of the PA and its related components is the same as the circuit on the element. By applying different supply voltage, the different transmission parameters are measured as Figure 2(b) showed. We can clearly observe that when the supply voltage increases from 3V to 5V (input 0 dB as example), S21 increases from -7 dB to 10 dB. Thus, the supply voltage of PA can effectively control its working state.

C. Metasurface Measurement

In the experiments, we fabricate a metasurface sample with 7*7 elements, within PCB technology, as showed in Figure 3(a). The measurement is performed in a standard chamber room, as depicted in Figure 3(b). The two-dimensional far-field result are measured at 5 GHz. The measured results are provided in Figure 3(c). We apply four different supply voltages (3V, 3.8V, 4.2V, and 5V) to achieve the transmission power from reduction to amplification. We can clearly observe four distinct transmission power, -10 dB, 0dB, 10dB and 20dB respectively.

III. CONCLUSION

In this paper, we proposed a transmissive metasurface based on active power amplifiers, to realize controllable power amplification and reduction. By integrated the power amplifiers on the metasurface and control the supply voltage, we successfully realize the amplitude manipulation from -10 dB to +20 dB. Comparing the previous works on the amplitude manipulation, we not only realize power amplification, but also the power reduction. The measured results show good agreement with our design, validating our ideas.

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REFERENCES


