Variable Reflection Angle Meta-Surface using Double Layered Patch Type FSS

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***Abstract* - This paper proposes the variable reflection angle meta-surface using the double layered structure which can change the scatter pattern simply by sifting other layer. It is clarified that the gradients of the element vs. the reflection phase are changed by the relative position between two layers in double layered patch type FSS (Frequency Selective Surface). It is found that the reflection angle with range of about -34 deg. to -2 deg. is obtained in the proposed meta-surface.**

***Index Terms* — Meta-surface, FSS, double layer**

I. INTRODUCTION

The meta-surface can realize the reflecting surface with optional characteristics by controlling the reflection coefficient and the reflection phase. Therefore, The Surface that reflects the electromagnetic wave to any direction is constructed by meta-surface technique [1]. Here, the structure of the meta-surface is decided by the design frequency and the reflection direction. When the reflection direction is changed to another direction by the set up point, the tunable capacitor or switches [2] are used.

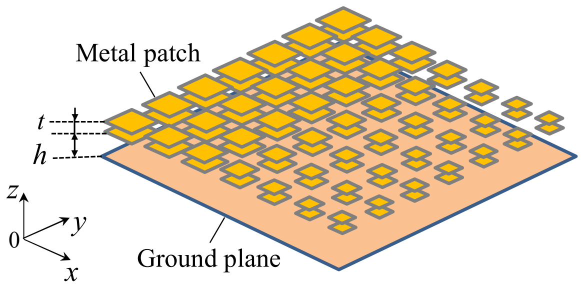
On the other hand, it is known that the difference of the reflection phase characteristics is occurred by the relative position of between two layers in double layered patch type FSS [3]. In this paper, the variable reflection angle meta-surface using the double layered structure is proposed.

II. STRUCTURE OF META-SURFACE

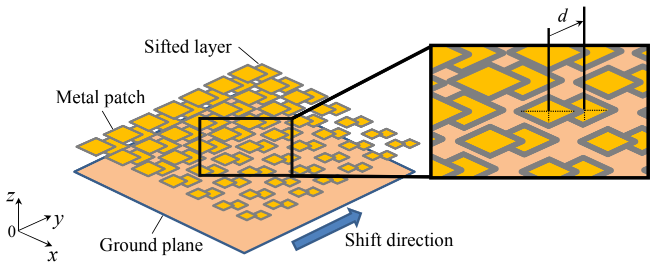
Fig. 1 shows the structure of double layered patch type meta-surface when all patches are same size. The meta-surface is composed of the metal patches and ground plane as shown in Fig. 1 (a). l is the length of the square metal patch on side. The first and second layer are shifted by d along y axis each other as shown in Fig. 1 (b). Therefore, when d/p=0.0, the meta-surface is stacked structure as shown in Fig. 1 (c). The meta-surface is also alternated structure when d/p=0.5 as shown in Fig 1. (d). Here, p is the unit cell size, t is the distance between layers and h is the distance between double layered patches and the ground plane.

III. REFLECTION PHASE CHARACTERISTICS OF DOUBLE LAYERED PATCH TYPE META-SURFACE

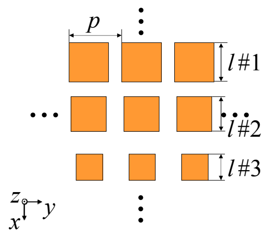
Fig. 2 shows an example of double layered patch type meta-surface's reflection phase characteristics when all

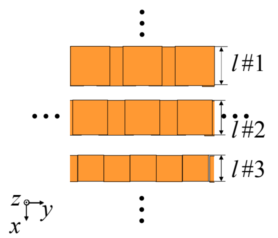


(a) Double layered patch type meta-surface



(b) Arrangement method of double layered





(c) d/p=0.0 (d) d/p=0.5

Fig. 1. Structure of meta-surface

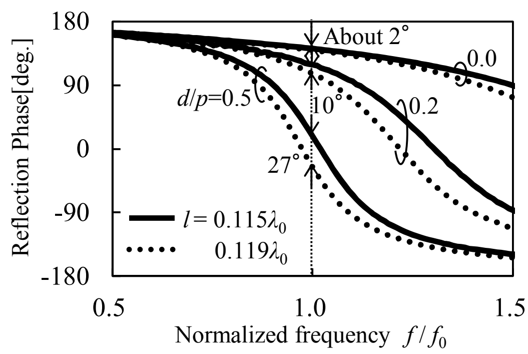


Fig. 2. Reflection phase characteristics when all patches are same size

patches are same size. The horizontal and the vertical axis denote the frequency and the reflection phase, respectively. The frequency is normalized by the design frequency f_0. The solid and dotted line shows the result in case of l=0.115λ_0 and 0.119λ_0, respectively.

It is found that the result in case of *d*/*p*=0.5 is shifted lower frequency side than the result in case of *d*/*p*=0.0 as shown in Fig. 2. As the result, the phase difference between the solid and dotted line in the design frequency is varied by *d*/*p*.

IV. Design of Variable Reflection Angle Meta-Surface

In this paper, the phase difference of the element each other is about 2 deg. when *d*/*p*=0.0 as shown in Fig. 3. Here, the reflection angle of the meta-surface is about 2.3 deg. which is obtained by (1).

$$\theta = \sin^{-1}\left(\frac{\lambda}{2\pi}\cdot\frac{\phi}{p}\right) \qquad (1)$$

Fig. 4 shows the relationship between the element number and the reflection phase. The element number shows the metal patch labeled number in Fig. 3. It is found that the gradient is almost constant when *d*/*p*=0.0 as shown in Fig. 4. When *d*/*p*=0.2 and 0.5, these gradients are also nearly constant and the value are about 10 and 27 deg., respectively. As the result, it is found that the gradients are changed by *d*.

Fig. 5 shows the relationship between *d*/*p* and the reflection angle of the meta-surface. It is found that absolute value of the reflection angle is also large when *d*/*p* is large. In this structure, the reflection angle with range of about -34 deg. to -2 deg. is obtained.

Fig. 6 shows the scattering pattern of the meta-surface when the electromagnetic wave enters from vertical direction. The solid, the broken and the dotted line denote the result in case of *d*/*p*=0.5, 0.2 and 0.0, respectively. It is found that the beam directions of each line are similar to Fig. 5.

V. Conclusion

The variable reflection angle meta-surface using the double layered structure was proposed. The difference of the reflection phase characteristics by the relative position of between two layers in double layered patch type FSS was clarified, and it was found that the gradients of the element vs. the reflection phase are changed by *d*.

As the result, the reflection angle with range of about -34 deg. to -2 deg. was obtained. Moreover, it was shown that the maximum direction of the scattering patterns is similar to design point.

References

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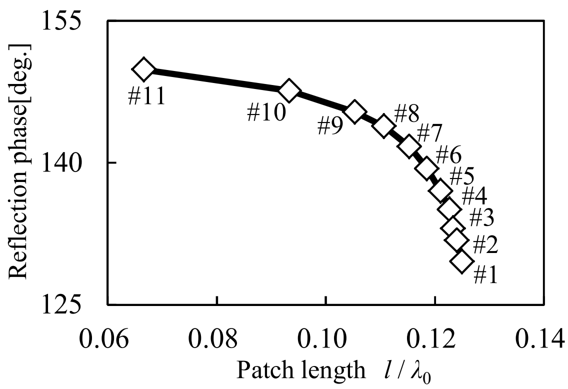

Fig. 3. Relationship between patch length and reflection phase

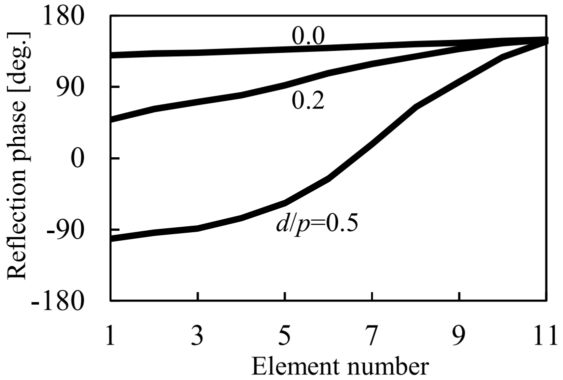

Fig. 4. Reflection phase characteristics

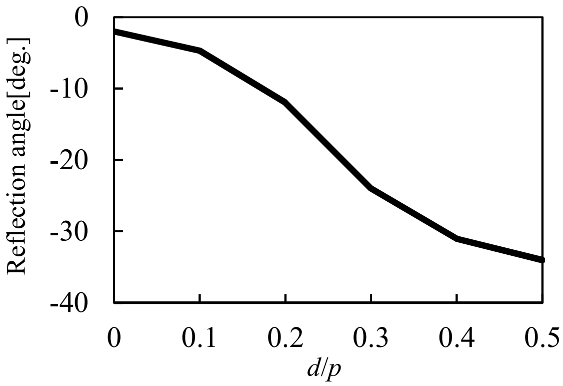

Fig. 5. Relationship between *d*/*p* and reflection angle

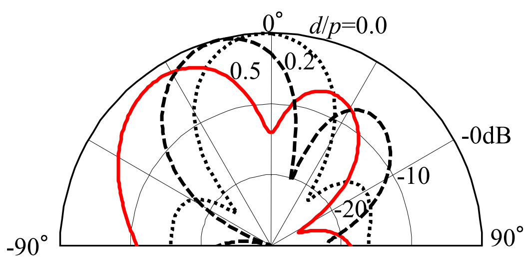

Fig. 6. Scattering pattern