Unit Cell Structure of AMC with Multi-Layer Patch Type FSS for Miniaturization

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***Abstract* - This paper describes unit cell structure of AMC (Artificial Magnetic Conductor) with a multi-layer FSS for miniaturization. Two types of unit cell, "Patch type" and "Grid type" unit cell are treated.**

Moreover, two types of FSS collocation method for multi-layer structure, "Stacked structure" and "Alternated structure" are considered. As the results of analysis, it is shown that the miniaturization effect is obtained only the case of "Patch type" FSS, and there is polarization dependence of AMC with the multi-layer FSS. It is also shown that the most miniaturization effect for unit cell size is obtained by "Alternated structure" when the layers are displaced just a half of the period of the unit cell, and the miniaturization effect is increased as the number of layers is increased.

***Index Terms* - AMC, patch type FSS, PMC characteristic, antenna reflecter.**

I. INTRODUCTION

An AMC has the PMC (Perfect Magnetic Conductor) characteristics in a specific frequency. The electromagnetic wave is reflected without phase rotation on the surface of the AMC with the PMC characteristics. The AMC is easily composed of the ground plane and FSS [1] [2]. The FSS is a surface which makes electromagnetic waves reflect or transmit in a specific frequency band [3]. As one of antenna applications, a low-profile antenna is realized by using the AMC reflector. Then, it is required that a unit cell size of the AMC reflector should be small [4].

This paper describes the optimal unit-cell structure of AMC equipped with the multi-layer patch type FSS for the miniaturization of unit-cell size.

II. STRUCTURE OF AMC WITH DOUBLE LAYERED FSS

Figure 1 shows the nit cell of AMC. As shown in Fig. 1(a), the AMC is composed of using the metal patch FSS and the ground plane.

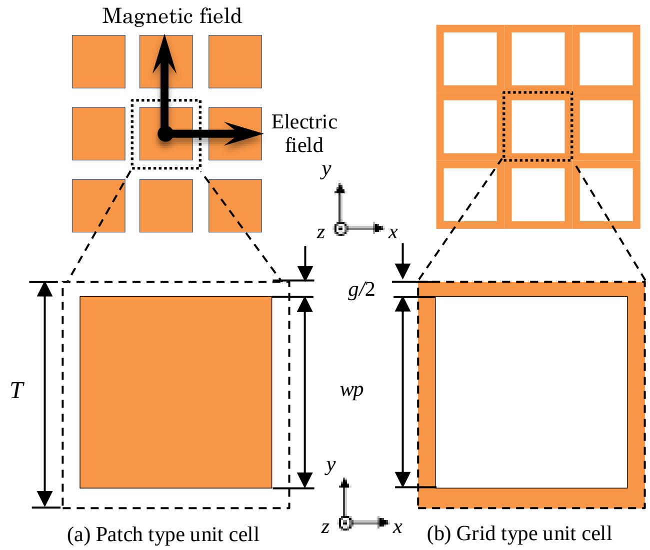


Figure 1. Unit cell of AMC

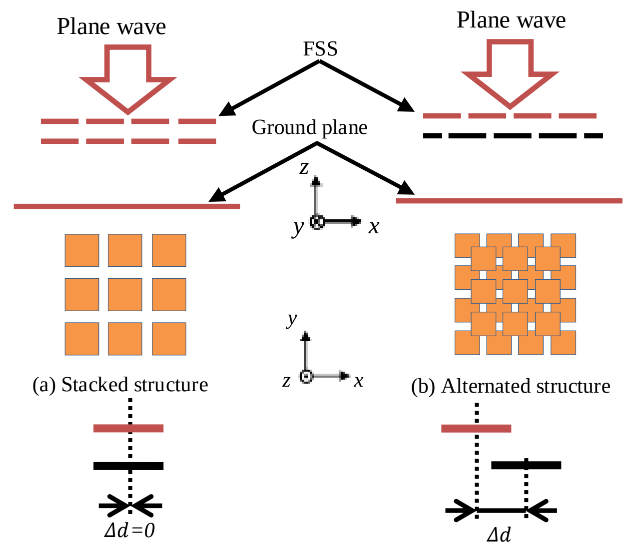


Figure 2. Structure of the AMC with double layer patch type and grid type FSS

The parameters of the patch type FSS structure are labeled as unit cell period *T*, patch width *wp*, gap of the patches *g*, patch type unit cell. The parameters of the grid type FSS structure is just opposite with patch type, as shown in Fig. 1(b). Figure 2 shows the structure of the AMC with double layer patch type FSS [5].

This section treats two type double layer structures. One is stacked structure as shown in Fig. 2(a), and the other is alternated structure as shown in Fig. 2(b). As shown in Fig. 2, Δd is the displacement length between layers. When Δd = 0, the layers are not displaced (stacked structure). When Δd is half of *T*, it is correspond to alternated structure. A plane wave is vertically incident from top to bottom as shown in Fig. 1. The electric field component and magnetic field component is directed in the x-axis direction and in the y-axis direction, respectively. Periodic boundary condition is used for the analysis of infinite structure, and the FDTD method is applied for the analysis. There is no dielectric between the double patch layers.

III. Reflection Characteristics of Patch and Grid Type AMC

Reflection phase characteristics of the AMC with patch type FSS is shown in Fig. 3. The solid line, the dotted line and the dashed line denote the reflection phase of AMC with the single layer, the double layered (stacked) and the double layered (alternated) FSS, respectively. The horizontal axis indicates the frequency normalized by f_p. Here, f_p is the frequency when the single layer patch type FSS shows the PMC characteristic. The vertical axis is reflection phase (we can see that the solid line of single layer patch type corresponds to the normalized frequency is 1 when the reflection phase is 0 (deg)). It can be seen that the frequency with PMC characteristics of double-layered AMC is shifted to the low frequency side. It means that the unit cell size is miniaturized by using double layered patch type FSS.

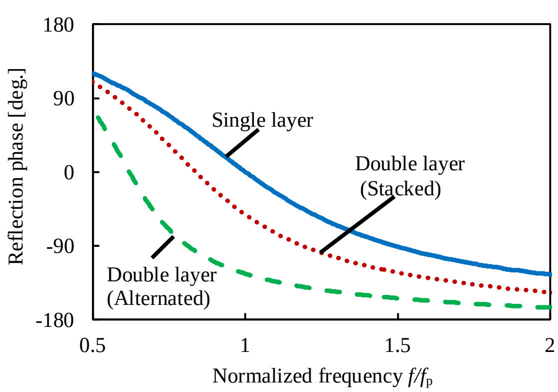


Figure 3. Reflection phase Characteristics of AMC with patch FSS

The reflection phase characteristics of the AMC with grid type FSS is shown in Fig. 4. The solid line, the dotted line and the dashed line denote the reflection phase of AMC with the single layer, the double layered (stacked) and the double layered (alternated) FSS, respectively. The horizontal axis indicates the frequency normalized by f_g. Here, f_g is the frequency when the single layer grid type FSS shows the PMC characteristic. The vertical axis is reflection phase (we can see that the solid line of single layer grid type corresponds to the normalized frequency is 1 when the reflection phase is 0 (deg)). It can be seen that the frequency with PMC characteristics of double-layered is shifted to the high frequency side. So it is said that the unit cell size can't be miniaturized by using double layered grid type FSS. From Fig. 3 and Fig. 4, we can say that the unit cell size can be miniaturized by using only the case of the patch type FSS for the double layered AMC.

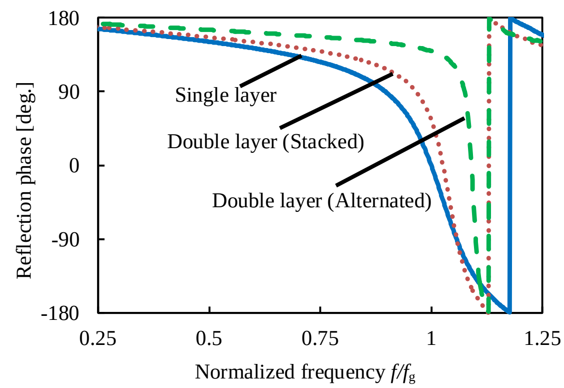
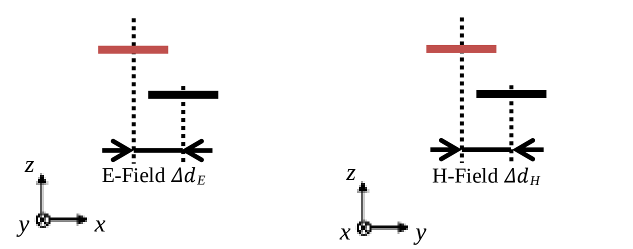


Figure 4. Reflection phase Characteristics of AMC with grid FSS

IV. Polarization Dependence of the Unit Cell Structure

In this section, effect of displacement between the upper and lower patch is discussed, and further identify the polarization dependence of the AMC unit cell structure.

The direction of polarization is as shown in Fig. 1. There are two displacement directions concerned with the polarization. One side of double layer is displaced to the direction of the magnetic field or the electric field as shown in Fig. 5.



(a) Displaced to the electric field (b) Displaced to the magnetic field

Figure 5. Displacement length Δd

E-Field Δd_E and H-Field Δd_H denote the displacement length to the electric field, and to the magnetic field, respectively.

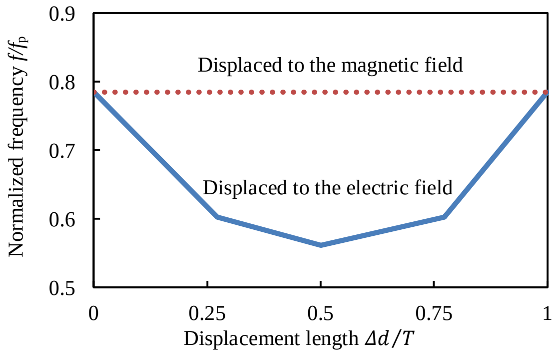


Figure 6. Relationship between Δd and PMC characteristics with patch type FSS

Figure 6 shows the relationship between the displacement length and the PMC characteristics with the patch type FSS when the upper and lower patches are displaced. The solid line and dotted line show the case that the layers are displaced in the direction of electric field (x-axis), and magnetic surface (y-axis) , respectively. The horizontal axis indicates the displacement length normalized by *T*. Here, *T* is the period of the unit cell. The vertical axis indicates the frequency normalized by f_p. When the layers are displaced to the electric field direction of the incident wave (x-axis), it can be seen that the frequency with PMC characteristics is shifted to the low frequency side. It can be seen that the lowest frequency of PMC characteristics is obtained when it is displaced just a half of the period of the unit cell. On the other hand, if the layers are displaced to the magnetic field direction of the incident wave (y-axis), it can be seen that the frequency with PMC characteristics does not change.

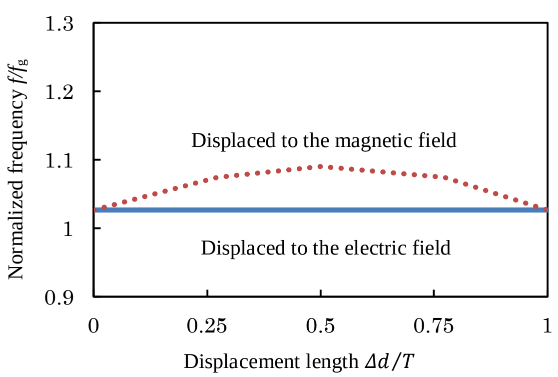


Figure 7. Relationship between Δd and PMC characteristics with grid type FSS

Figure 7 shows the relationship between the displacement length and the PMC characteristics with the grid type FSS when the upper and lower patches are displaced. The solid line and dotted line show the case that the layers are displaced in the direction of electric field (x-axis), and magnetic surface (y-axis), respectively. The horizontal axis indicates the displacement length normalized by *T*. The vertical axis indicates the frequency normalized by f_g. When the layers are displaced to the electric field direction of the incident wave (x-axis), it can be seen that the frequency with PMC characteristics does not change. On the other hand, if the layers are displaced to the magnetic field direction of the incident wave (y-axis), it can be seen that the frequency with PMC characteristics is shifted to the high frequency side. It can be seen that the highest frequency of PMC characteristics is obtained when it is displaced just a half of the period of the unit cell.

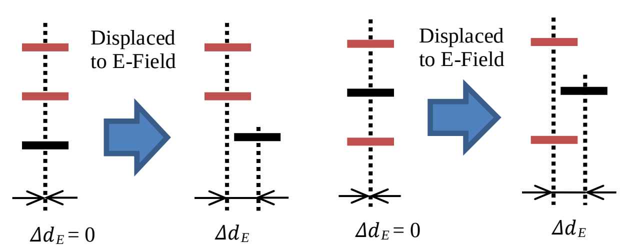
Therefore, when the patch type layers are displaced to the electric field direction of the incident wave (x-axis), the frequency with PMC characteristics is shifted to the low frequency side. But if the grid type layers are displaced to the magnetic field direction of the incident wave (y-axis), the frequency with PMC characteristics is shifted to the high frequency side.

We were confirmed that there is polarization dependence of AMC with the double-layer FSS, but the unit cell size can be miniaturized by using only the case of the double layered patch type, and the best miniaturization effect is obtained when it is displaced just a half of the period of the unit cell.

V. Unit Cell Structure of AMC with Multi-Layer FSS

A. Relationship between Δd and PMC characteristics by the collocation method

According to the above discussion, the unit cell size can be miniaturized by using only the case of the double layered patch type, when the layers are displaced to the electric field direction. So we are considering the AMC with the multi-layer patch type FSS only the direction to the electric field. Figure 8 shows the model of the displacement length Δd of the three-layer (lower and middle). Figure 8(a) shows the layers are displaced only the lowest layers, and Fig. 8(b) shows the layers are displaced only the middle layers.



(a) The three-layer (lower) (b) The three-layer (middle)

Figure 8. Displacement length Δd of the three-layer (lower and middle)

The results are shown in Fig. 9. The solid line, the dotted line, the dashed lines denote the frequency with PMC characteristics of the AMC with the double layer FSS, the three-layer (lower) FSS and the three-layer (middle) FSS, respectively. The PMC characteristics of the AMC with three-layer patch type FSS is shifted to lower frequency than that of the double layer. And it is best effective when it has been displaced as the Fig. 8(b).

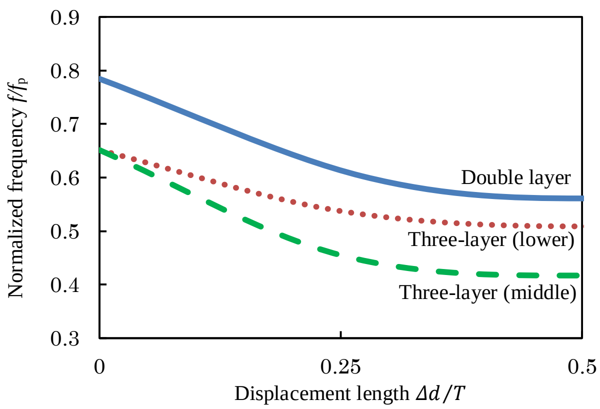


Figure 9. Relationship between Δd and PMC characteristics by the collocation method

B. Relationship between Δd and PMC characteristics by the number of layer

Figure 10 shows displacement length Δd of the three-layer when it is displaced to electric field little by little. The double layer and four-layer are collocated as the same method as the three-layer. The collocation method of the three-layer AMC is the same as the Fig. 8(b), when Δd = T/2.

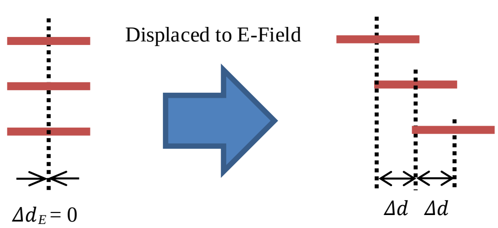


Figure 10. Displacement length Δd of the three-layer

The results are shown in Fig. 11. The solid line, the dotted line, the dashed lines denote frequency with PMC characteristics of AMC with the double layer FSS, the three-layer FSS and the four-layer FSS, respectively. It can be seen that the frequency with PMC characteristics is shifted to the low frequency side by increasing number of layers. It is also found that the most miniaturization effect for the unit cell size is obtained when the layers are displaced just a half of the period of the unit cell.

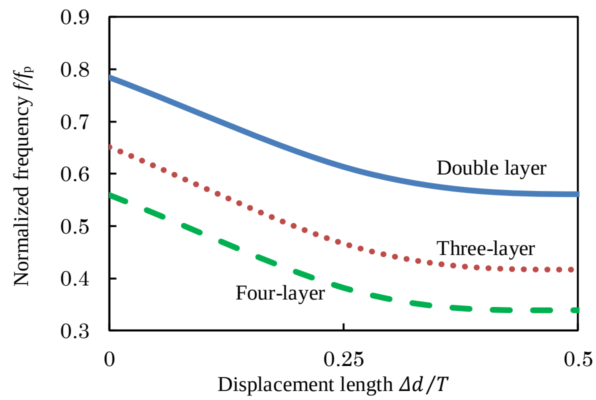


Figure 11. Relationship between Δd and PMC characteristics by the number of layer

VI. Conclusion

It was found the optimal structure of AMC with double layer patch type FSS for miniaturization of unit cell. As the result of studies, it was shown that the unit cell could be miniaturized, and further identify the polarization dependence of the AMC unit cell structure. The PMC characteristics of the AMC with multi-layer patch FSS could be obtained as the same as the double layer. We were confirmed that there was polarization dependence of AMC with the multi-layer patch FSS. It was also found that the most miniaturization effect for the unit cell size was obtained when the layers were displaced just a half of the period of the unit cell, and the effect of the miniaturization was increased as the numbers of layers was increased.

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