

Reduction of Reflection Loss from Dielectric Plate by Reflection-phase Control of Frequency Selective Surface

Goro Nomoto, Masamu Chiba, Kunio Sakakibara, and Nobuyoshi Kikuma
 Department of Electrical and Mechanical Engineering, Nagoya Institute of Technology
 Gokiso-cho, Showa-ku, Nagoya, 466-8555 Japan
 Email: sakaki@nitech.ac.jp

Abstract - The thickness of the dielectric plate is comparable with the wavelength, therefore, can not be neglected in high-frequency band. The reflections from the dielectric plate surfaces are canceled out of phase only when the thickness is identical to one half of the wavelength. However, they are not canceled in general and reflection loss is generated. Frequency Selective Surface (FSS) is equipped on one side of the dielectric plate. Reflection loss can be reduced by controlling the reflection phase of the FSS to be opposite phase to the reflection phase of the other dielectric surface. The control range of the reflection phase of the FSS is investigated in this work. The basic operation to reduce the reflection loss is demonstrated in this paper.

Index Terms — Frequency selective surface, Periodic structure, Phase control.

1. Introduction

When a dielectric plate like radome or glass is in front of an antenna, it causes the loss due to the reflection from the surface and the dielectric loss of the material. The reflection loss is small only when the thickness of the dielectric plate is identical to one half of the wavelength in the dielectric. However, their thicknesses are arbitrary in general, therefore they are not always canceled and reflection loss is generated. A Frequency Selective Surface (FSS) works as a filter. Only the signal in the limited frequency band transmits [1], [2].

An FSS is equipped on one side of the dielectric plate. Using the fact that an FSS can control the phase of the reflected wave [3], the reflections from the both surfaces on the dielectric plate is canceled out of phase. Consequently, the reflection loss of the dielectric plate is reduced. The control range of the reflection phase of the FSS is investigated and the effect for reflection loss reduction is verified in this paper.

2. Principal and Structure

An FSS is equipped on one side of the dielectric plate, and is designed to reduce reflection loss by controlling the reflection phase of the FSS as shown in Fig. 1. The reflections from the both surfaces of the dielectric plate are synthesized by certain phase difference depending on the thickness of the dielectric plate. They can be canceled out of phase by changing the reflection phase from the FSS surface.

To cancel the reflections for any thickness of the dielectric plate, wide control range of reflection phase is necessary for FSS. A square slot FSS [1], [4] and a double sprit-ring slot FSS [5] shown in Fig. 2 were investigated by periodic analysis [4]. When the electromagnetic wave incidents to the FSS, the slot operates as a capacitor and the conductor operates as an inductor. Therefore, these FSS is equivalent to the L-C parallel circuit. When the perimeter of the ring slot and the slot length in the sprit-ring slot is one wavelength and a half wavelength, respectively, the FSSs become

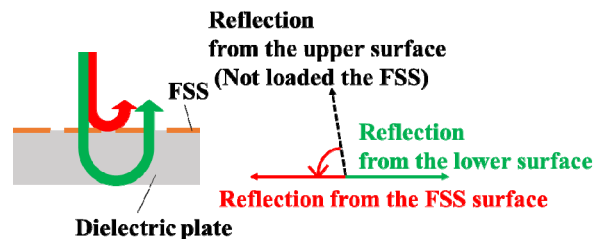


Fig. 1. Principle for reflection loss reduction of the dielectric plate using FSS.

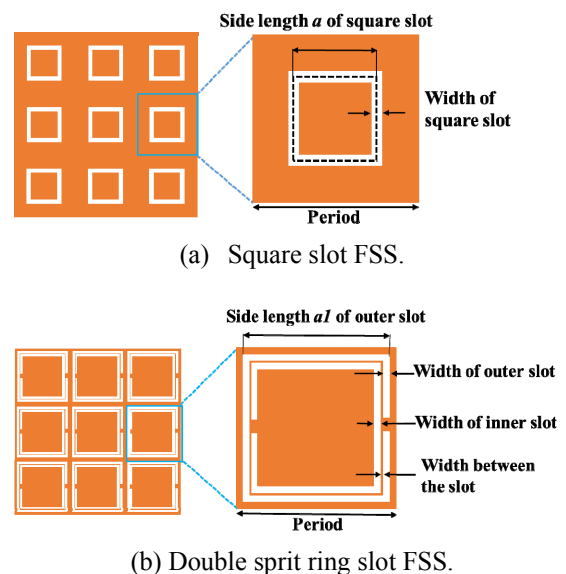


Fig. 2. Structure of the FSS.

resonant and the reflection phase is identical to 180 deg. To control the reflection phase, the length of the FSS is set to be a non- resonant.

3. Analysis Result

The square slot FSS and the double split-ring slot FSS were loaded on one side of the dielectric plate. The relative permittivity of the dielectric plate was 2.17 and the thickness was 6.0 mm. The individual reflection phase of one surface loaded the square slot FSS when changing the side length a of the square slot is shown in Fig. 3. The reflection phase of the dielectric plate when the FSS is not loaded is also shown in Fig. 3. When nothing is loaded to the dielectric plate, the reflection phase is 180 deg. When the side length of the square slot FSS is 2.3 mm, the control range of the reflection phase is from 137 to 222 deg. Although the resonant frequency changed, the control range of the reflection phase did not change. When the side length a is longer, the wavelength for the resonant frequency becomes longer. Therefore, the resonance frequency shifted to the low frequency. For a particular frequency, by changing the side length of the square slot, the reflection phase changes approximately 40 deg.

The individual reflection phase of one side loaded the double split-ring slot FSS is shown in Fig. 4. When the side length $a1$ of the outer slot in the double split-ring slot FSS was 1.65 mm, the control range of the reflection phase was from 140 deg. to 219 deg. which is similar range with the ring slot. The resonant frequency also shifted to lower by changing the side length $a1$ of the outer slot.

The overall reflection coefficient including the reflections from the both surfaces of the dielectric plate loaded the square slot FSS is shown in Fig. 5. When the side length was 2.3 mm, reflection loss decreased from -13.3 dB to -20.1 dB at 30.7 GHz.

4. Conclusion

By loading the square slot FSS and the double split-ring slot FSS on one side of the dielectric plate, it is confirmed that the reflection phase can be controlled over 40 deg. By

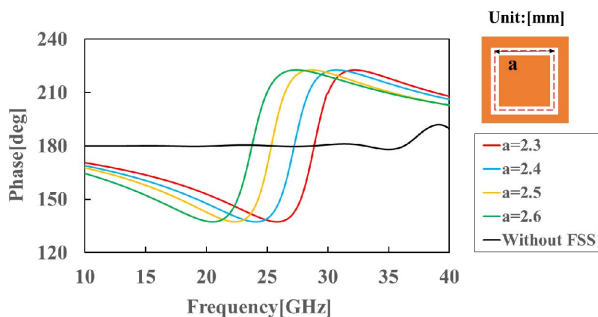


Fig. 3. Reflection phase of the individual surface loaded the square slot FSS on the dielectric plate, changing the slot length a .

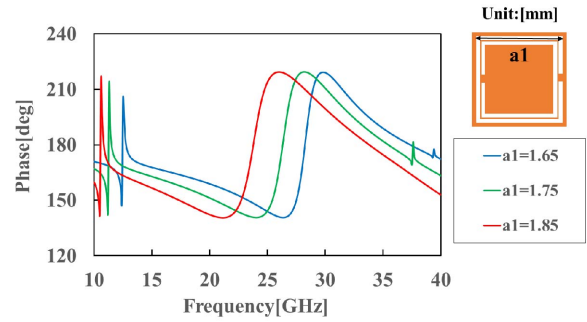


Fig. 4. Reflection phase of the individual surface loaded the double square slot FSS on the dielectric plate changing the outer slot length $a1$.

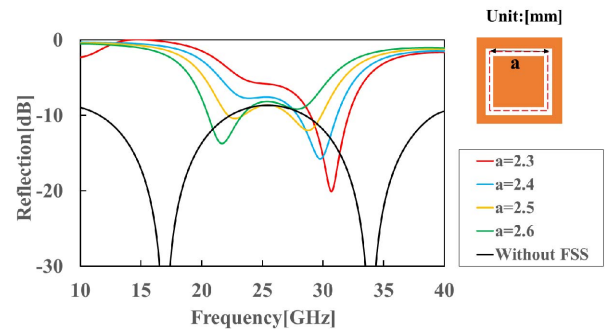


Fig. 5. Reflection coefficient of the dielectric plate loaded the square slot FSS.

controlling the reflection phase, it is possible to reduce the reflection loss of the dielectric plate. FSS with more control range of reflection phase is expected in the future.

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