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Miniaturization of Period of Dual-band Frequency Selective Surface by using C-shaped Ring Slots

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***Abstract* – For shielding various communication equipments, it is advantageous to miniaturize the size of period of FSS. To decrease the size of the period of dual-band FSS for LTE, Bluetooth and Wi-Fi, C-shaped ring slots are proposed. As a result of the electromagnetic simulation, the proposed model achieves 43.2% miniaturization of the FSS period even with the comparable property as the conventional ring slots.**

***Index Terms* — Frequency selective surface, C-shaped ring slot, band pass, multiband.**

I. Introduction

Various-band radio waves increase in growing wireless technologies for many applications. Undesired waves cause property degradation or malfunction of electronic equipments. To solve this problem, Frequency Selective Surface (FSS) has been developed [1]. FSS is periodic arrangement of elements on metallic plate. When electromagnetic waves propagate to the FSS, only the waves at some specific frequencies pass through the FSS, and the others are reflected. Owing to this property, FSS is variously applied as electromagnetic filters for wireless devices [1], [2]. Recent wireless devices equip multiple communication channels such as 3G and LTE mobile phone, Wi-Fi, Bluetooth and so on. Some of the various frequency bands are often used simultaneously. Therefore, broadband FSS or multiband FSS is required [3]. Furthermore, because the shielding area using FSS is often limited, it is necessary to miniaturize the size of the period in the design for periodic property. We miniaturized dual-band FSS by applying C-shaped ring slots in this study [4], [5]. Results of electromagnetic analysis are indicated in this paper.

II. Principle and Design of Multi-band FSS

Band pass property and relatively small period were realized by using ring slot FSS. Dual-band operation was achieved by using multi-ring slots with two different sizes. Figure 1(a) shows the pattern layout of the conventional multi-ring slot FSS which is composed of 2x2 small inner rings for higher resonance and an outer ring for lower resonance [6]. 2x2 configuration extends bandwidth from the bandwidth of the single-ring slot.

To miniaturize the size of the period, C-shaped ring slot (CRS) is proposed in this paper. CRS resonates when the loop length is equal to a half wavelength, while O-shaped ring slot resonates when the loop length is one wavelength. Therefore, the size of the period can be reduced to approximately a half the loop length.

The design process of this FSS for three-frequency operation is as follows; at first, determine the dimensions of inner CRSs to transmit the waves of two higher frequencies. Next, the interval *d* is determined not to couple the inner and outer slots. Finally, the dimension of the outer CRS is determined to transmit the wave at the lowest design frequency.

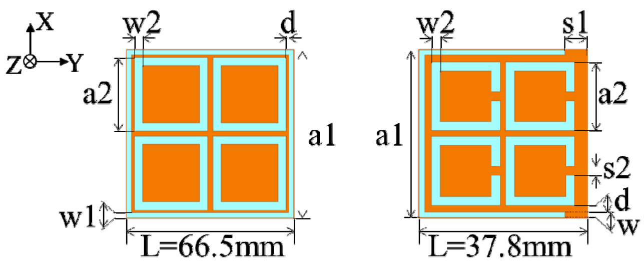

Fig. 1. Pattern layouts of the period of FSSs.

In this paper, the dual-band FSS is designed to operate for use in LTE (700 MHz, 2.1 GHz), Bluetooth (B/T) and Wi-Fi (2.4 GHz) bands. The conventional model is composed of one outer Square Loop Slot (SLS) and four inner SLSs with 2x2 arrangement as shown in Fig. 1(a) [6]. On the other hand, the proposed model is composed of one outer CRS and four inner CRSs with 2x2 arrangement as shown in Fig. 1(b). The dimensional parameters of the both models shown in Figs. 1(a) and (b) are listed in Table.1.

Both models are printed on one side of polycarbonate (ε_r=2.9) plates. Analysis model is shown in Fig. 2. Air is filled above and below the dielectric plate. Plane wave whose polarization is +Y direction incidents in –Z direction.

Transmission and reflection properties are analyzed by finite element method. For boundary conditions, Perfect Electric Conductor (PEC) and Perfect Magnetic Conductor (PMC) are set on the side walls. Therefore, a two-dimensional infinite periodic structure can be simulated even in the analysis of one period.

As a result of the design for 700 MHz, 2.1 GHz and 2.4 GHz, the outer slot is reduced to only three sides of square. The length L=66.5 mm of the period in the conventional model reduces to 37.8 mm in the proposed model.

TABLE I
DIMENSIONAL PARAMETERS OF BOTH MODELS IN FIG. 1

Parameters	Conventional model [mm]	Proposed model [mm]
L	66.5	37.8
a1	66	37.5
w1	2	1
s1	—	5
d	0.5	1.75
a2	30	15.5
w2	3.25	2
s2	—	2

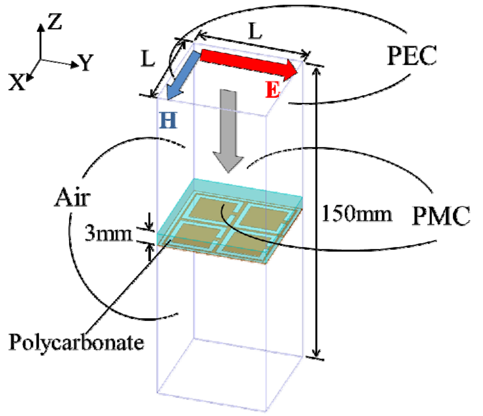

Fig. 2. Analysis model.

III. SIMULATED PERFORMANCE

The scattering coefficients of reflection S_{11} and transmission S_{21} of the conventional and the proposed models are shown in Figs. 3 and 4 with electric field distributions at the design frequencies. Transmission property is obtained at the three bands (LTE, Bluetooth and Wi-Fi), as well as the conventional model.

A small anti-resonance is observed at 2 GHz in the proposed model in Fig. 4, however, the coupling is suppressed by optimizing d. It is observed that the outer and the inner slots resonate independently at each design frequency. From the field distribution in Fig. 3, the conventional model resonates by loop length of O-shaped ring slot with a wavelength. On the other hand, as shown in the field distribution in Fig. 4, the proposed model resonates by loop length of C-shaped ring slots with a half wavelength. Therefore, transmission properties are obtained at the identical frequency bands although the size of the period is almost a half.

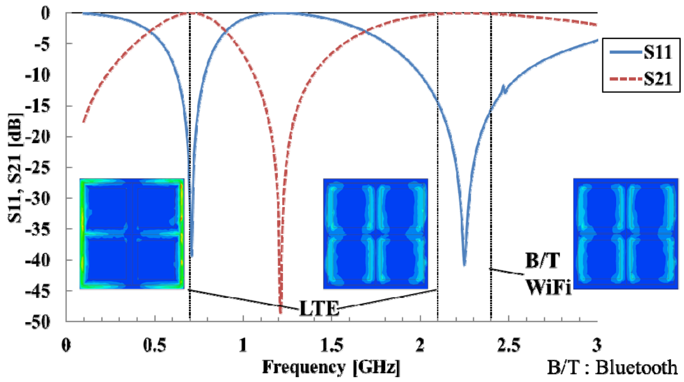

Fig. 3. Scattering coefficients of the conventional model.

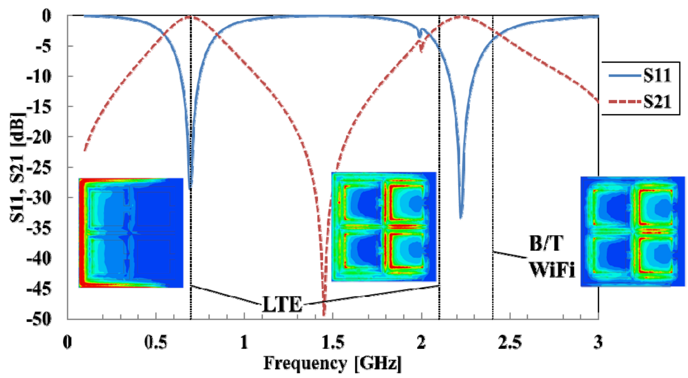

Fig. 4. Scattering coefficients of the proposed model.

IV. CONCLUSION

The C-shaped ring slots are proposed to miniaturize the size of the period of FSS to almost a half for easy installation to any electric devices. Furthermore, two resonant frequencies are controlled independently by the loop length with coupling control by d.

As a result of the design, the period of the dual-band FSS of the proposed model achieves 43.2% miniaturization compared with the conventional model.

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