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A Novel Uni-Planar Compact EBG Structure

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Abstract—The radiation and propagation characteristic can be improved by the microstrip structure of the electromagnetic band-gap, which is becoming miniaturized today. In order to reduce the influence to the width of the band-gap brought by the miniaturization of the UC-EBG structure, a novel UC-EBG structure is brought out. The band-gap width is guaranteed, meanwhile, the unit length is reduced to $0.1\lambda_g$. Results of measurement indicate that this structure is effectively miniaturized, has an excellent performance, and can be used in the antenna or microwave circuit fields.

1. INTRODUCTION

The advancement in the wireless communication technology demands highly efficient and portable devices. So, for the wireless devices, compactness is an attractive feature. But in a compact device a very small space is required to share by various radiation sources. In the planar antenna and circuit technology, mutual coupling between these sources increases. Also, noise level of the system increases, and electromagnetic interferences (EMI) become significant. These effects degrade the system performances. Excitation of surface wave inside the substrate material of planar circuits affects the system negatively. To speed up any devices, mutual coupling reduction and suppression of unwanted noises are very important.

Electromagnetic band-gap (EBG) structure, which is a periodic structure composed of metal and medium. EBG can show band rejection characteristics when propagating electromagnetic wave. Results of previous researches indicate that the EBG structure can improve the performance of telecommunication systems in many aspects [1–9].

A novel Uni-planar Compact EBG (UC-EBG) structure is designed in this letter. This structure is small in size and suitable for portable and compact telecommunication systems. The results of simulation and actual measurement indicate that this UC-EGB structure has a good band-gap characteristic, with a much smaller size than other UC-EGB structures.

2. EBG STRUCTURE DESIGN

The technology of UC-EBG is mature and simple, but the requirement of process precision is relatively high. Compared with EBG structures of other types, UC-EBG structure has flexible miniaturization manners. Similar to other metal medium EBG structure, UC-EBG structure is equivalent to a parallel LC model, whose resonant frequency makes the UC-EBG structure present a high impedance band-gap character [10], as shown in (1) and (2).

$$\omega_0 = \frac{1}{\sqrt{LC}} \tag{1}$$

$$Z_s = \frac{j\omega L}{1-\omega^2 LC} \tag{2}$$

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where L and C are equivalent parallel inductor and capacitor of the UC-EBG structure, which are acquired from the inductance and capacitance behavior of the structure characteristics. Usually a thin microstrips is equivalent to inductance, and parallel microstrips are equivalent to capacitance. For UC-EBG, the essence of the miniaturization is to implement equal equivalent inductor and capacitor in a smaller area.

Inductance can be increased using a broken line form, but parasitic capacitance is introduced at the same time and hence inductance is decreased [10]. Equivalent capacitance is increased in a spiral form, but limited by the band-gap width, as shown in (3).

$$BW = \frac{1}{\eta}\sqrt{\frac{L}{C}} \tag{3}$$

In this work, a compact UC-EBG structure is proposed. Equivalent inductor and capacitor are added in the equivalent parallel circuit of the structure. A satisfactory band-gap is acquired, meanwhile miniaturization is implemented to the UC-EBG structure. The unit structure is shown in Figure 1.

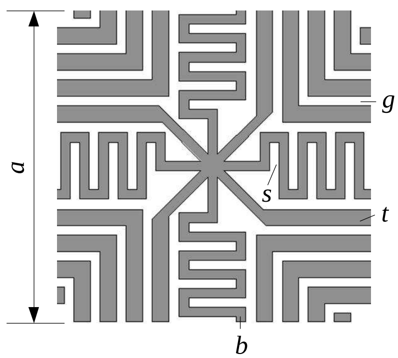

Figure 1. UC-EBG structure cell.

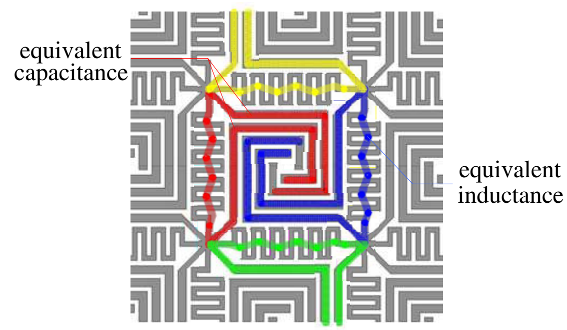

Figure 2. UC-EBG structure and its equivalent LC circuit.

This novel compact UC-EBG structure is composed of 4 inductance arms and 4 capacitance arms. Inductance arms are designed in a broken line form, which effectively lengthens the thin microstrips in adjacent UC-EBG units, and increases the inductance between units next to each other. Capacitance arms are designed in a spiral form, which effectively increases the plate area between neighboring capacitance arms from neighboring units, and hence increase capacitance in unit area. The structure relationship of equivalent circuits between different units is shown in Figure 2.

It can be seen from the symmetric and mirrored structure of the UC-EBG unit that a parallel resonant circuit is composed of a broken line inductor and a spiral capacitor is formed between each two neighboring units. Both the inductor and capacitor have large values. As a result, both the parallel equivalent inductance and capacitance are increased, and the resonant frequency of a UC-EBG unit is effectively decreased. Meanwhile the miniaturization is implemented without affecting the band-gap width.

3. ANALYSIS AND TESTING

By adjusting the width of the spiral arm t, the band-gap g, the width of the broken line inductor, and the number of turns, the equivalent inductance and capacitance can be tuned to resonant at the band-gap frequency. An ideal set of structure parameters are acquired by simulation using suspended microstrip method, listed in Table 1.

As shown in Figure 3, assume that $S_{21} < -10\,\text{dB}$, the band-gap frequency range of the compact UC-EBG structure is between 4.95 GHz and 5.75 GHz, the center frequency is 5.35 GHz, the relative band-gap width reaches 15%, which is suitable for a broad-band communication system. It can be seen that S_{21} attenuates very fast in the stop band. In more than 90% of the stop band, S_{21} has a

Table 1. UC-EBG structure parameters (unit: mm).

a	b	t	g	s
6.6	0.2	0.35	0.25	0.2

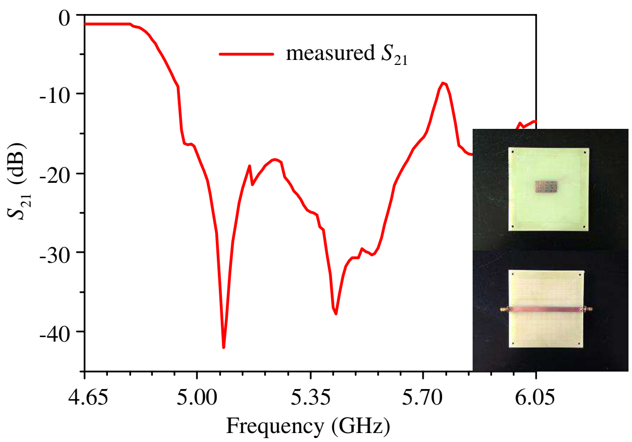

Figure 3. S_{21} of novel UC-EBG structure based on suspended microstrip method.

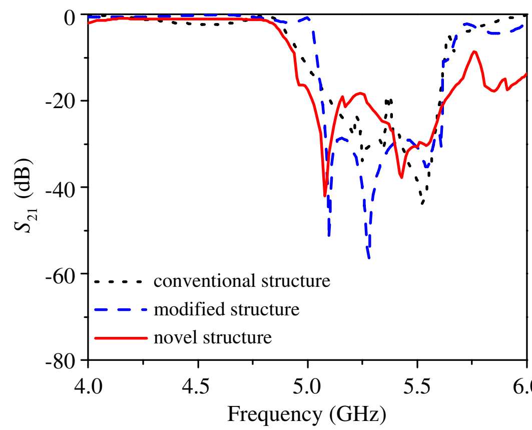

Figure 4. S_{21} comparison of UC-EBG structure.

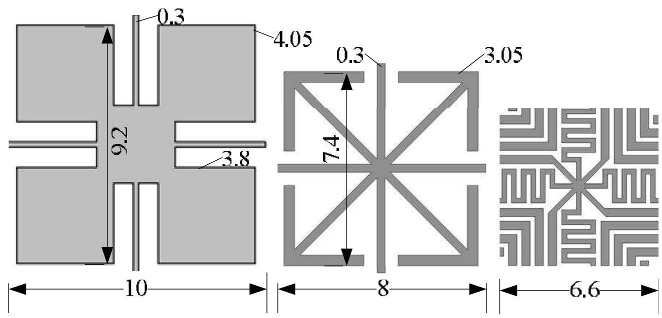

Figure 5. Size comparison of UC-EBG structure (unit: mm).

falloff better than -20 dB. Besides, S_{21} keeps very stable outside the stop band, which stands for a nice transmission characteristic. These characteristics presents an excellent performance of the band-gap.

In order to illustrate the miniaturization feature of this structure, the conventional UC-EBG structure [7] and improved UC-EBG structure [6] are designed based on the same stop band frequency. The characteristics of these band-gaps are shown in Figure 4, and the structures are shown in Figure 5.

It can be seen from Figure 3 that all the three EBG structures show an obvious characteristic and a good out-of-band transmission performance, which means that the electromagnetic wave within the band-gap range is well suppressed. The band-gap width satisfies the requirement of a broad band communication system.

The outline and dimension of the UC-EBG structures is shown in Figure 5. The novel UC-EBG structure has a smaller unit size, the length of side of which is 66% of that of the conventional structure, and 82.5% of that of the modified structure. The area of the compact structure is 44% of the conventional UC-EBG structure, and the geometrical length is 1/10 of the cut-off wavelength, which make it more suitable for small size devices and for enhancing the wave radiation and propagation performance of the system.

4. CONCLUSION

A novel compact UC-EBG structure is designed. Through the optimal design to the planar compact band-gap, miniaturization is implemented, meanwhile the band-gap width is guaranteed. The results of testing and simulation indicate that this structure has a small size and excellent performance. There can be a promising future in the application of the antenna and microwave circuit fields.

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