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A NOVEL COMPACT AND WIDE-BAND UNI-PLANAR EBG STRUCTURE

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Abstract—A novel uni-planar electromagnetic Band Gap (EBG) structure incorporated with inter-digital capacitor and meandered line inductor (ML-ID-EBG) is presented, this novel structure significantly enlarges the fringe capacitance to reduce sized cells, as well as increases the equivalent inductance to widen the relative bandwidth. Its design is detailed in this paper, and several experimental results are presented, the improved properties of the proposed ML-ID-EBG are examined, as compared with a conventional UC-EBG and a novel EBG incorporated only with inter-digital capacitor (ID-EBG).

1. INTRODUCTION

In recent years, there has been growing interests in investigating electromagnetic Band-Gap (EBG) structures, and diversified kinds of EBG structures have been suggested for the applications of microwave circuits and antennas [1–7]. To make EBG more suitable for actual applications, much effort has been devoted to realize compact size for EBG structure. Recently high-impedance surfaces, as a successful compact EBG structure consisted of small metal pads with grounding vias, have been exclusively investigated [3, 4]. Uni-planar Compact EBG (UC-EBG), introduced by Yang et al., are also compact in size and have been even more interesting because of the easy fabrication, low cost, and compatibility with standard planar circuit technology [5–7].

According to the notion of UC-EBG, a novel uni-planar compact EBG structure, which can been considered as one kind of ameliorated UC-EBG incorporated with inter-digital capacitor and meandered line inductor (ML-ID-EBG), is proposed in this paper, and the experimental results shows that the novel ML-ID-EBG is prospectively useful for realizing more compact size and wider relative bandwidth.

2. DESIGN

One unit cell of the proposed ML-ID-EBG, together with that of the conventional UC-EBG and one novel EBG incorporated only with inter-digital capacitor (ID-EBG), is shown in Fig. 1.

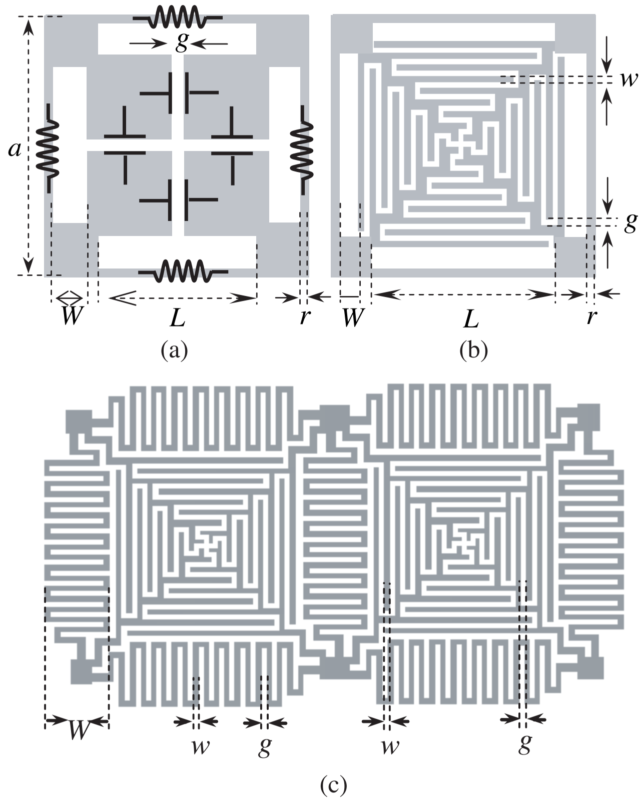


Figure 1. Unit cells of (a) the conventional UC-EBG, (b) the novel ID-EBG, and (c) the proposed ML-ID-EBG.

The unit cell of the conventional UC-EBG lattice consists of pericardial narrow lines and four square pads at central section, as shown in Fig. 1(a). The convergence of electric currents on pericardial narrow strips introduce the equivalent inductance L, and the gaps between the conductor edges of square pads introduce the equivalent capacitance C, thus a two-dimensional periodic LC network is realized which results in the frequency band-gap, the center frequency of the band-gap is determined by $\omega_0 = 1/\sqrt{LC}$, and the relative bandwidth $\Delta\omega/\omega_0$ is direct proportion to $\sqrt{L/C}$.

In order to achieve an even more compact EBG structure, the equivalent capacitance C and inductance L should be increased by all means.

Firstly, the concept of inter-digital capacitors is introduced to enlarge the equivalent capacitance C [8], the four square pads at central section of unit cell have been substituted by an inter-digital structure, which results in much bigger fringe capacitor, and a novel unit cell of ID-EBG is obtained and shown in Fig. 1(b).

On second thoughts, to widen the relative bandwidth of band-gap, the increase of equivalent inductance L is more significant, so the linear strips in unit cell are replaced as meandered lines. Such a novel unit cell of ML-ID-EBG structure, as shown in Fig. 1(b), is constructed, which will win much lower frequency band-gap as well as wider relative bandwidth.

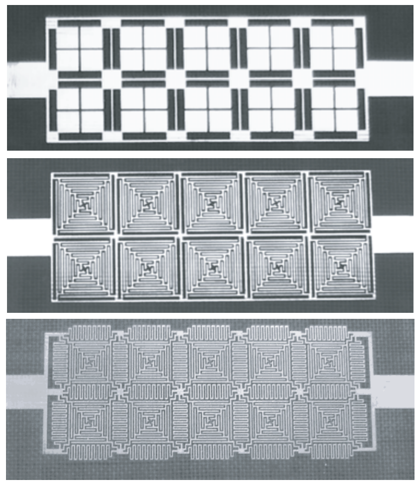
3. EXPERIMENTAL RESULTS

To verify the properties of the proposed ML-ID-EBG, a novel ML-ID-EBG, together with an ID-EBG and a conventional UC-EBG, are designed for comparison with one another. These periodic lattices are all printed on a dielectric slab with dielectric constant $\varepsilon_r = 2.65$ and thickness 1.5 mm, the periodic spacing are chosen as $a = 7.3$ mm.

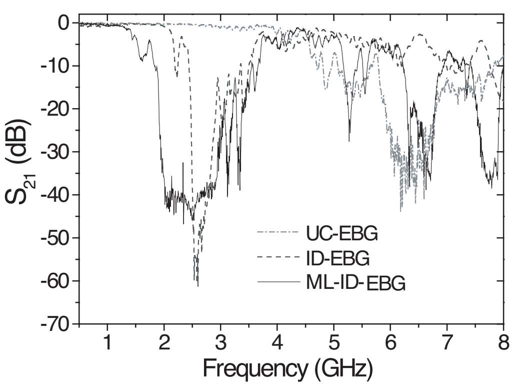
For the ML-ID-EBG structure, the element parameters are assumed as $W = 1.85$ mm, the strip width and space of the inter-digital structures and meandered lines are all chosen as $w = g = 0.15$ mm. For the conventional UC-EBG, the width W and length L of the insets are optimized using HFSS, and the element parameters are evaluated as $W = 0.9$ mm, $L = 5$ mm, $r = 0.1$ mm, $g = 0.2$ mm. For the ID-EBG, the element parameters are $W = 0.385$ mm, $L = 6.43$ mm, $r = 0.1$ mm and $w = g = 0.15$ mm.

To validate the properties of the ML-ID-EBG, some experiments about these EBGs have been carried out.

Firstly, a 2×5 lattice of these EBGs are mounted on a grounded dielectric slab and connected with 50 Ω microstrip lines at both ends as a filter structure, the photograph of the top side of these structures are shown in Fig. 2(a). As the measured results using Advantest R3767CG vector network analyzer, the S_{21} parameters of these EBG structures are shown in Fig. 2(b). Evident stop-bands have been observed in all cases, the stop-band of the proposed ML-ID-EBG is from 1.8 to 3.7 GHz, and that of the ID-EBG is from 2.4 to 3.5 GHz, they are all much lower than that of the UC-EBG (5.7–7.0 GHz), and the frequency reduction are 57% and 54% respectively. The relative bandwidth of the ID-EBG is 37%, while that of the ML-ID-EBG is up to 64%.



(a)



(b)

Figure 2. (a) Photograph of top side of there EBG structures connected with microstrip lines and (b) measured S_{21} parameters of these EBG structures.

Secondly, a 2×5 lattice of these EBGs are etched on the ground plane of a $50\,\Omega$ micro-strip lines, the bottom view of these EBG structures are shown in Fig. 3(a). The measured S_{21} parameters of the ML-ID-EBG express a much lower stop-band (2.1–3.0 GHz) relative to that of the conventional UC-EBG (5.6–8.9 GHz), as shown in Fig. 3(b). The stop-band of the ID-EBG is from 2.5 to 3.0 GHz, and the relative

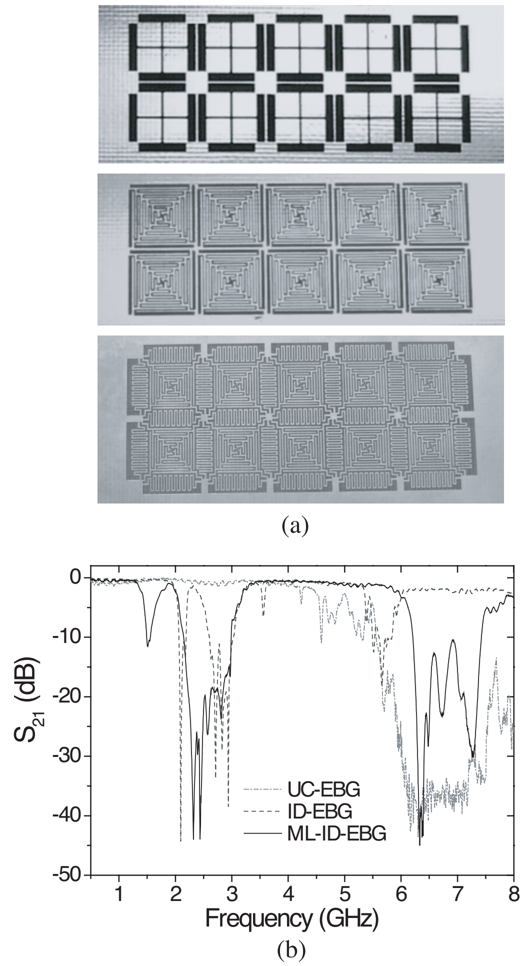


Figure 3. (a) Photograph of bottom side of micro-strip line with EBGs etched in the ground plane and (b) the measured S_{21} parameters of these EBG structures.

bandwidth of the ML-ID-EBG (35%) is much wider than that of the ID-EBG (18%).

Finally, to measure the band-gap of surface waves, a 25×25 array of the ML-ID-EBG is fabricated and measured. The photographs of one part of the structure are shown in Fig. 4(a). There are two probes stood at a pair of relative corners of the array, which are used to excite and receive TM surface waves. As the measured results, shown in

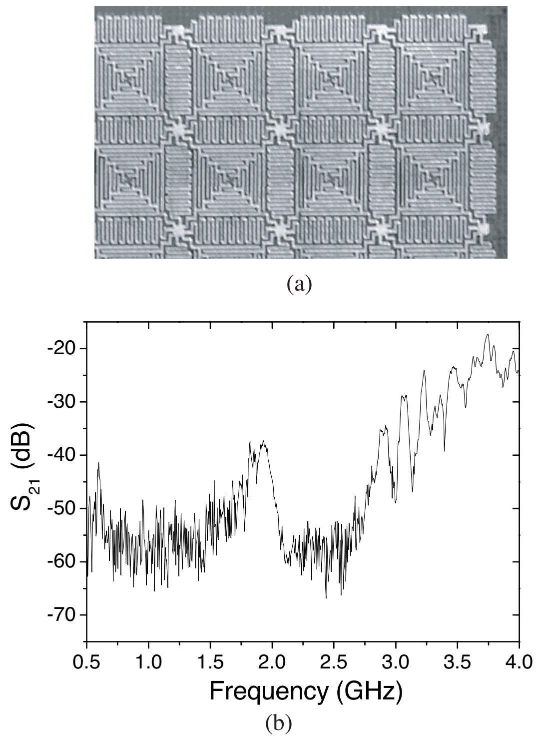


Figure 4. (a) Photograph of one part of ML-ID-EBG and (b) the measured S_{21} parameters of the TM surface wave.

Fig. 4(b), one evident stop-band has been observed, it is from 2.0 to 2.9 GHz, and the relative bandwidth is 36%. It is verified that even better compactness and wider relative bandwidth are found in the novel ML-ID-EBG structure.

4. CONCLUSION

A novel uni-planar electromagnetic Band-Gap (EBG) scheme is presented, the proposed structure can be considered as an ameliorated uni-planar compact EBG (UC-EBG) Surface incorporated with inter-digital structure to reduce sized cells, as well as increases the equivalent inductance to widen the relative bandwidth. Its design is detailed in this paper, and several observations have been made, from the comparisons with the conventional UC-EBG and one EBG incorporated only with inter-digital capacitor (ID-EBG), the better compactness and wider relative bandwidth of the novel ML-ID-EBG is verified effectively, it shown that this novel EBG scheme will be very valuable in practical applications.

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