An Improved Hexagon Electromagnetic Band-Gap Structure with Filter Size Reduction Applications

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1. Introduction

The electromagnetic band-gap (EBG) structures, initiated by the photonic band-gap (PBG) ideals [1], have been drawn much attentions due to the wave forbidden features for stop bands and the slow wave characteristics for passbands. Applications for antenna/array performance enhancements [2-3], filters designs [4], and electromagnetic interference reductions [5] are reported in literatures. Moreover, the uniplanar square-shape EBG is proposed for easier fabrications with good insertion loss performance, increasing the versatility of the EBG applications [6].

Recently a uniplanar hexagon EBG has been proposed with better slow wave factor performances, suited for the circuit size reduction applications [7]. The insertion loss, however, is a little higher than the conventional square shape EBG structure [8]. This paper presents an improved hexagon EBG by combining the advantages of the square and the hexagon EBGs, for the similar applications of circuit size reductions.

The designed EBG is placed at the ground plane of the microstrip line to increase the distributed capacitances and inductances for slowing the wave propagation. The simulations are performed by the commercial software using finite-element-method (FEM) to check the insertion loss and the slow wave behavior for passband, and the rejection for the stop band. These simulation results are confirmed by the measured data. A typical band-pass filter in printed-circuit-board (PCB) is analyzed and designed at 3.45 GHz to show the availability of the proposed EBG structure, with verifications of experiments.

2. Improved Hexagon Electromagnetic Band-Gap Structure

Figure 1 shows the basic configurations of the original hexagon EBG and the improved version for reducing the insertion loss where the ground plane of the microstrip line is etched by a 2-dimensional periodic pattern in honeycomb shape with the different cell details. Since the original hexagon structure has too complicated branch/gap structure to introduce higher insertion loss, especially at the band near the cutoff frequency, the hybrid approach using the square pattern which is quite good at pass-band insertion loss is adapted, with the almost same slow wave factor performances to the original hexagon EBG. With the proper adjustments of the cell size, the branch length, and the gap distance, the band-gap can be controlled to the desired frequency bands. The substrate for the EBG in this study is Rogers RT 6010 with the relative dielectric constant of 10.2 and the tangent loss of 0.0023. The whole structure which dimensions are listed in Table I is simulated by Ansoft HFSS electromagnetic software for S-parameter frequency responses.

The simulation results for the two hexagon EBG structures are shown in Figure 2 where the stop frequency is designed at 10 GHz. One can find the insertion losses are -2.54 dB and -0.68 dB at 8 GHz for the original hexagon EBG and the improved version respectively. The additional simulation and measurement data of the slow wave factor β/k_0 for the two hexagon structures are shown in Figure 3 where very little differences at the low band can be observed. The other advantage of the improved hexagon EBG is about the uniformity for the slow wave factor as the microstrip is shifted from the original location as shown in Figure 3. On the other hand, the slow wave factor comparisons of the improved hexagon and the conventional square EBGs are given as shown in Figure 4 where the measurements are performed at the RT 6010 substrate for the same cutoff frequency. Thus more effective size reduction purpose for the improved hexagon EBG rather than the conventional square one can be obtained in microwave circuit applications.

3. Band-Pass Filter Design Using Improved Hexagon EBG Structure

The capacitive-coupling band-pass filter for WiMAX application (3.4 GHz ~ 3.53 GHz) is presented using the improved hexagon EBG to reduce the circuit size as shown in Figure 5. The simulations and measurements are shown in Figure 6 including the reflection and transmission quantities. The slow wave factor is about 1.133 at the center frequency 3.45 GHz with –30 dB band-gap rejection around 6 GHz to suppress the spurious of the microstrip filter. The insertion losses of the simulation and the measurement are –2.07 dB and –2.69 dB respectively while the size is reduced about 7 mm. On the other hand, the spurious rejection performance is quite good as summarized in Table II up to the fifth harmonics where f_0 is 3.45 GHz.

References

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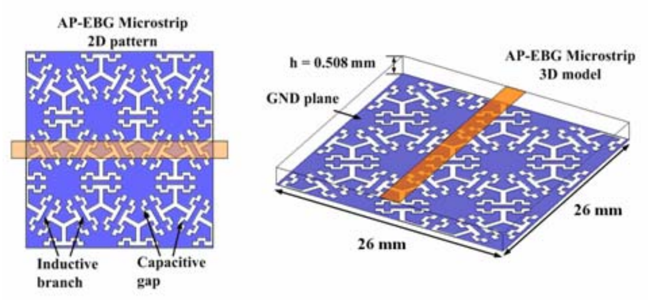
Table I: Dimensions of the improved hexagon EBG.

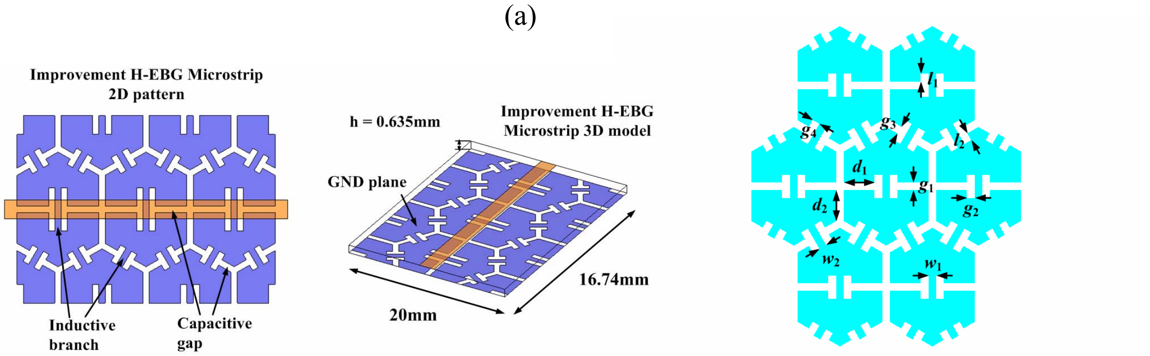
g_1	0.3 mm	l_1	0.4 mm	w_1	0.3 mm
g_2	0.3 mm	l_2	0.4 mm	w_2	0.3 mm
g_2	0.3 mm	d_1	0.82 mm	thickness	0.635 mm
g_4	0.2 mm	d_2	0.82 mm	line width	0.6 mm

Table II: Harmonic response of the capacitive-coupling filter using improved hexagon EBG.

	f_0	$2f_0$	$3f_0$	$4f_0$	$5f_0$
S_{11}	-22.4 dB	-0.59 dB	-1.92 dB	-2.71 dB	-4.28 dB
S_{21}	-2.69 dB	-57.5 dB	-26.1 dB	-27.5 dB	-19 dB



(a)



(b)

Figure 1: (a) Original hexagon EBG and (b) improved hexagon EBG.

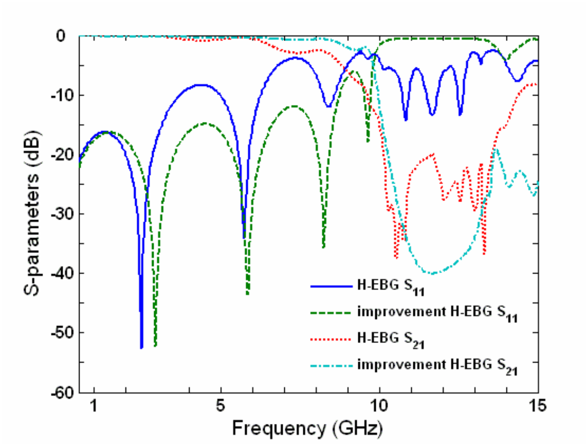


Figure 2: Simulated S-parameters for original and improved hexagon EBGs.

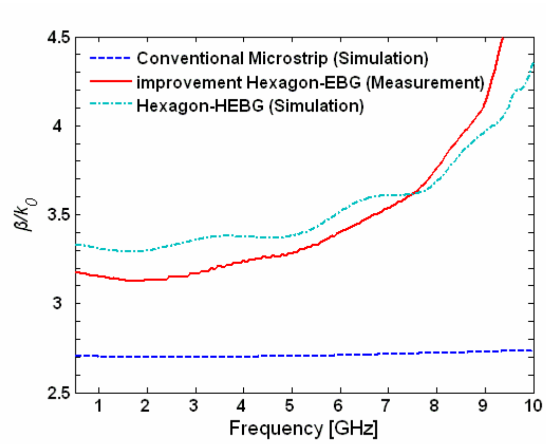


Figure 3: Simulation and measurement slow wave factors for original and improved hexagon EBGs.

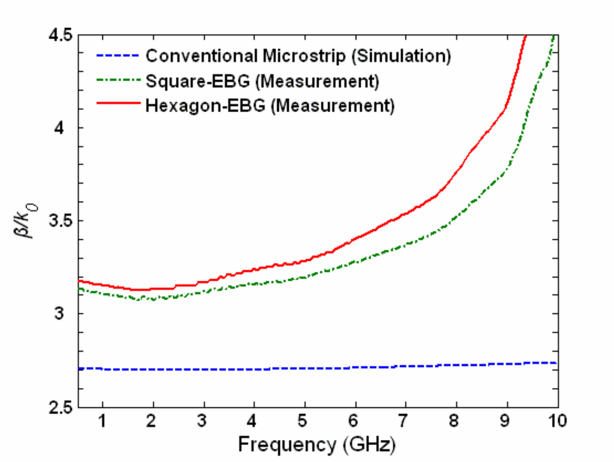
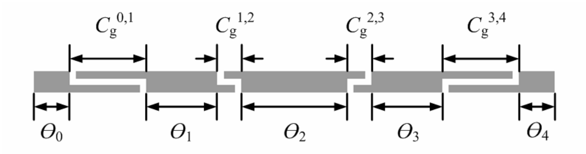


Figure 4: Measured slow wave factors for conventional square and improved hexagon EBGs.



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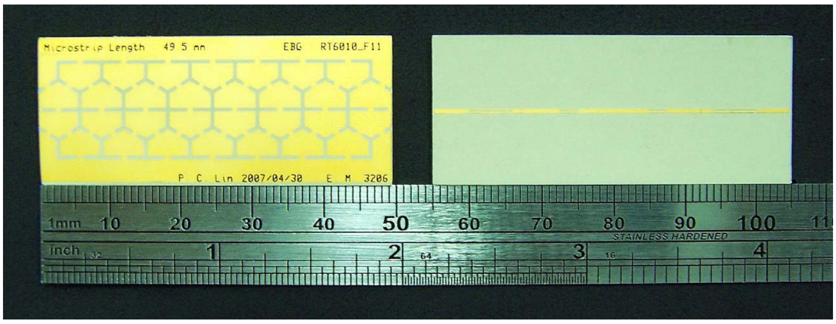

(b)

Figure 5: (a) Schematics and (b) photograph of the capacitive-coupling band-pass filter design using improved hexagon EBGs.

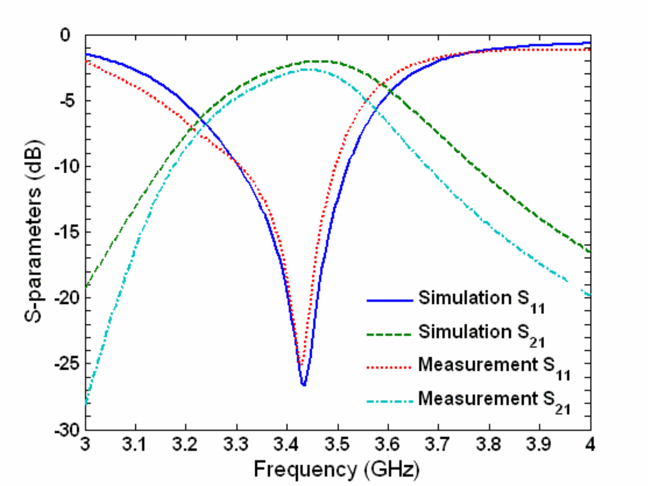

Figure 6: Simulated and measured results for capacitive-coupling band-pass filter with improved hexagon EBGs.