Planar EBG Structure in Application of SAR Reduction of Tablet PC

Chen-Yu Wang[1], Ding-Bing Lin[1]

[1] Department of Electronic Engineering, National Taipei University of Technology, No.1, Sec. 3, Chunghsiao E. Rd. Taipei, 10608, Taiwan.

***Abstract* –In this paper, a planar EBG structure is designed for SAR reduction in tablet PC application. We simulated EBG reflection phase by HFSS and measured SAR by SAR test equipment (iSAR) in order to verify. The experiment results prove the proposed planar EBG is useful in reducing SAR of tablet PC under WLAN operation frequencies (2400MHz-2483.5MHz).**

***Index Terms* — Electromagnetic Band Gap (EBG), Specific Absorption Rate (SAR).**

I. Introduction

The EBG structure often been used in antenna design, enhances antenna's gain [1] and reduces SAR values [2].

SAR is an indication of the amount of radiation that is absorbed into body when using a mobile device. SAR values are usually expressed in units of watts per kilogram (W/kg) in either 1g or 10g of tissue.

In this experiment, we insert the proposed EBG structure into the middle of antenna and the rear side of tablet PC for SAR reduction.

II. Proposed Planar EBG Structure and Design

The reflection coefficient can be given by equation 1, where Z_S is impedance of EBG, η_0 is impedance of vacuum.

$$\Gamma = (Z_s - \eta_0) / (Z_s + \eta_0) \quad (1)$$

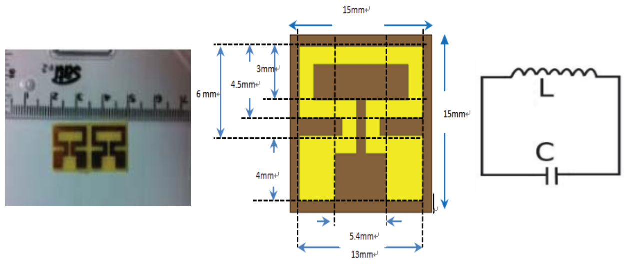
When EBG surface impedance have low loss, which implies the real part of Z_S is very small, thus $Z_S = jX$, the reflection phase ($\angle\theta$) can be calculated as equation 2.

$$\angle\theta = \frac{\angle[\pi - \tan^{-1}(X/\eta_0)]}{\angle[\tan^{-1}(X/\eta_0)]} = \angle[\pi - 2\cdot\tan^{-1}(X/\eta_0)] \quad (2)$$

In order to achieve the infinity impedance ($Z_S = jX = \infty$) at resonant frequency, we have to design the pattern on PCB's planar EBG to be similar as parallel LC circuit, and the resonant frequency has to be closed 2442MHz (WLAN central frequency). If the design principles of EBG complies the above two conditions, then we could say that the EBG surface impedance performs as perfect magnetic conductor (PMC) at 2442MHz. The characteristic of PMC has $\Gamma = +1$ and reflection phase equal 0^{o}. It is in expectations to see PMC characteristic from EBG surface impedance.

Fig. 1(a) shows the photo of proposed planar EBG structure. The size of proposed EBG is 30mm × 15mm and printed on no-ground substrate FR4 ($\varepsilon_r = 4.4$) with thickness 0.4mm. Detail dimensions of unit cell are shown in Fig. 1(b).

The equivalent circuit mode of proposed planar EBG shows in Fig. 1(c).



(a) (b) (c)

Fig. 1. (a) Proposed planar EBG structure. (b) Dimension of unit cell proposed planar EBG. (c) Equivalent circuit of proposed EBG structures.

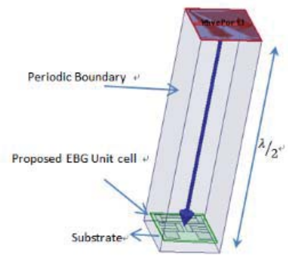


Fig. 2. HFSS reflection phase simulation model.

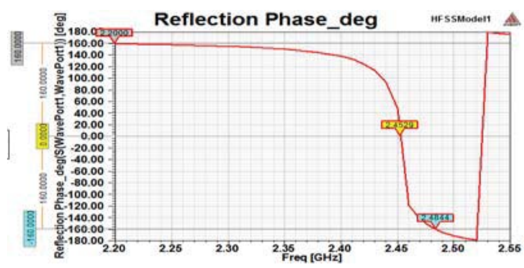


Fig. 3. HFSS reflection phase simulation results of proposed EBG.

The reflection phase model of proposed EBG structure from HFSS simulation is shown in Fig. 2. A plane wave illuminates on EBG surface, and infinite periodic conditions are given by the pairs of PEC and PMC boundary conditions.

This design leads the resonant frequency at 2452.9MHz.

Fig. 3 shows the computed reflection phase of the proposed planar EBG. According to the reflection phase simulation results, the frequency corresponding to the zero degree reflection phase is 2452.9MHz. In this case, the frequency span covers 284MHz (2200MHz-2484MHz) for spread between +160° to -160°.

III. SAR Measurement Results and Conclusion

All of 1g and 10g measurement data of SAR 1g/10g are from iSAR tester. The photo of test equipment is shown in Fig. 5. We used iSAR to test SAR twice. The first time, we tested SAR of tablet PC only. The second time, we inserted proposed EBG between tablet PC antenna and rear side of tablet PC then tested SAR values. Two times measurement photo of internal table PC are shown as Fig. 4(a) and Fig. 4(b).

SAR measurement results are shown in Table I. It can find the SAR values were reduction caused by insertion proposed EBG.

TABLE I
The SAR Measurement RESULTS comparison

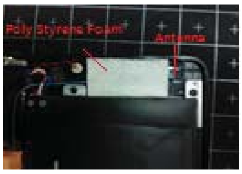
WLNA Channel	Central Frequency	SAR Measurement Results			
		Without EBG		With EBG	
		1g	10g	1g	10g
1	2412	0.484	0.246	0.13	0.0675
2	2417	0.64	0.33	0.185	0.0948
3	2422	0.77	0.386	0.237	0.123
4	2427	0.634	0.328	0.237	0.122
5	2432	0.48	0.236	0.146	0.0756
6	2437	0.449	0.219	0.105	0.0544
7	2442	0.532	0.267	0.128	0.0649
8	2447	0.736	0.355	0.19	0.0987
9	2452	0.806	0.407	0.251	0.127
10	2457	0.591	0.292	0.174	0.0887
11	2462	0.387	0.19	0.0911	0.0476
12	2467	0.393	0.197	0.0867	0.0431
13	2472	0.56	0.274	0.139	0.0701

To avoid the side effect by inserting the proposed EBG in tablet PC. We measured return loss (S_{11}) twice. The first measurement is without insertion proposed EBG into tablet PC. The second is with the proposed EBG into tablet PC. The two measurement raw data are shown in Fig. 6. It shows that antenna of tablet PC return loss (S_{11}) in WLAN operation frequencies are all under -10dB. It means also that antenna could be worked normally at WLAN operation frequencies in condition of with and without proposed EBG in tablet PC.

IV. Conclusion

In this study, simulation and experiment are performed. The SAR experiment results prove proposed EBG structure is useful in SAR reduction of tablet PC at WLAN operation frequencies. And the antenna return loss (S_{11}) is also a consideration in this paper. We measured the return loss (S_{11}) of antenna only and compared to return loss (S_{11}) of antenna with EBG structure. Both S_{11} are all under -10dB at WLAN operation frequencies. It complies with principles of antenna design.

The distance between antenna and EBG structure is quiet important and which affects a lot antenna performance. Moreover, the different distance could bring different results in return loss. In this case, we used 5mm thickness polystyrene foam to separate antenna and proposed EBG structure. The 5mm thickness polystyrene foam and EBG structure are not effect antenna performance and 5mm thickness polystyrene foam is still acceptable for tablet PC assembly.



(a)

(b)

Fig. 4. (a) Table PC without EBG. (b) Table PC with EBG.

Fig. 5. SAR measurement system (iSAR).

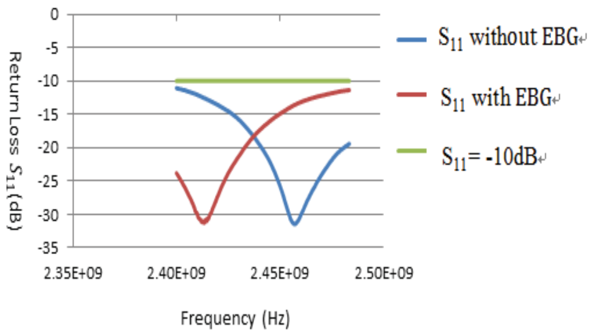


Fig. 6. Antenna return loss (S_{11}) compared to return loss (S_{11}) of antenna with EBG structure.

References

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