Indonesian Journal of Electrical Engineering and Computer Science
Vol. 5, No. 3, March 2017, pp. 593 ~ 598
DOI: 10.11591/ijeecs.v5.i3.pp593-598

Flexible Dual Band Dipole Antenna with Electromagnetic Band Gap

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Abstract

Flexible dual band dipole antenna incorporates with Electromagnetic Band Gap (EBG) to improve the well-known low profile characteristics of dipole antenna. The antenna operates at 2.45 GHz and 5.8 GHz which is printed on Fast film with 0.13 mm thickness. While the EBG is designed at 5.8 GHz by using Arlon AD350 with 1.016 mm thickness. EBG works as a ground plane for the antenna and helps by improving the realized gainandradiation pattern. Besides, EBG also act as a filter as the resonant frequency of the antenna is close to the EBG band gap. The 2.45 GHz of is eliminated while the performances of antenna at 5.8 GHz is improved. Thus the realized gain is increased up to 6.86 dB and the back lobes are clearly reduced. The designs of dipole antenna with EBG application such as Wifi and others on-body communication devices.

Keywords: *flexible, dipole antenna, electromagnetic band gap, realized gain and radiation pattern*

1. Introduction

In recent years, there has been increasing interests in investigating flexible system technology. Flexible antennas are the main method implemented in body centric communications [1-2]. However, there will be performances distortions as the flexible antennas apply on human due to distinct properties of human body itself [3]. Thus, investigation and development of flexible antennas becomessignificant interests [4-7].

The performances degradations include the frequency detuning, bandwidth reduction and radiation distortions as the flexible antenna is placed on human body. The radiation that penetrates into the human cells becoming a major health concern [3]. Then, EBG structure which introduce interesting properties is used in order to improve the antenna performances. Lately, the EBG structure have been used extensively toimprove the performances of the antenna by improving the gain and reducing the radiation exposure to the human body [8-14].

In 2001, the EBG structure is successfully improves around 0.2 dB gain and 0.59 FBR of helix antenna in “Stopband Characteristics Prediction with Suspending Microstrip Line for Rectangular Spiral EBG Structure” [15]. While in 2007, modified slotted patch electromagnetic band gap structure for antenna array is designed by O. Ayop and friends. They found that there is improvement of radiation pattern with reduced back lobe with an extra gain of 1 dB compared to the antenna alone [16]. Zhu and Langley (2007) conclude that placing the EBG behind the antenna considerably reduces back radiation by at least 13 dB while improving gain by up to 3 dB in a direction away from the body [17].

In this paper, the performances of flexible dual band dipole antenna with EBG are explained. Flexible dual band dipole antenna incorporates with EBG to improve the well-known low profile characteristics of dipole antenna. EBG works as a good ground plane for the antenna and helps by improving the realized gain and radiation pattern.

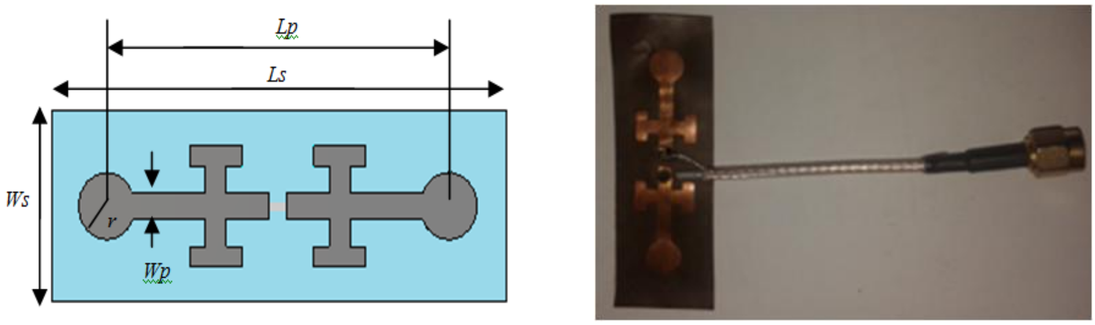
2. Research Method

2.1. Flexible Dipole Antenna

Figure 1(a) and (b) show of the structure and prototype of dual band dipole antenna thus resonates at 2.45 GHz and 5.8 GHz. Both of the radiating elements are in U-Shape patch

Received November 30, 2016; Revised February 1, 2017; Accepted February 20, 2017

with the 50 Ω Sub Miniature Version A (SMA) connector are connecting both of them. The radiating elements is printed on flexible substrate material which is Fast Film (thickness of 0.13 mm and dielectric constant of 2.7).



(a) (b)

Figure 1. Flexible dual band dipole antenna with its dimensions in mm:
(a) design structure and (b) prototype
(W_S = 20, L_S = 60, W_P = 2.5, L_{P1} = 40, L_{P2} = 00and r = 3.34)

2.2. Electromagnetic Band Gap

Figure 2 shows the unit cell of EBG structure. There is a square substrate with a main square patch at the centre of the substrate. There are 8 branches connected to the main square patch which all of the branches are designed alternately between the narrow branches with the connected sub-square branches. Noticed that there is capacitance which is introduced by the gaps between neighbouring patches and inductance is produced by the narrow branches. The patch is printed on Arlon AD350 with 1.016 mm thickness and 3.5 of dielectric constant

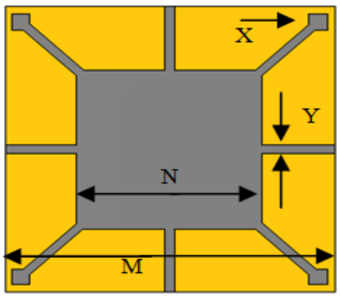
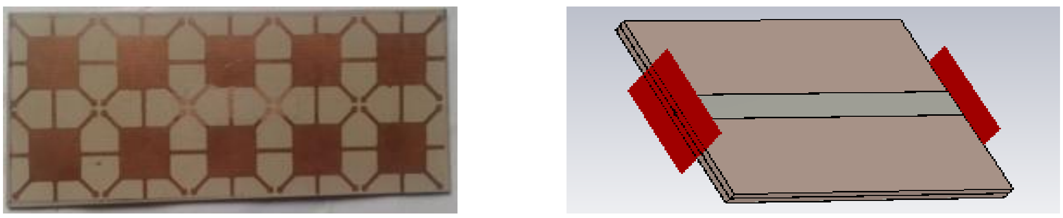


Figure 2. EBG structure with its dimensions in mm
(M= 15.73, L_S = *00*, N = 8.74, X= 0.87, Y = 0.43)



(a) (b)

Figure 3. The 5 by 2 of EBG structure: (a) protoptype and (b) layout view of transmission line method

While Figure 3(a) is 5 by 2 of EBG prototype structure while Figure 3(b) shows the layout view of transmission line method [18-21] in order to evaluate the band gap. The initial work started by designing a transmission line on the supporting substrate thus same with the substrate material. The width of transmission line is 2.2 mm for Arlon AD 350 substrate material. There are two 50 Ω SMA ports at both end of the 5 by 2 arrays structure connecting the transmission line and ground plane of the EBG structure.

2.3. Flexible Dual Band Dipole Antenna with EBG

EBG structures works as a ground plane for flexible dual band antenna at certain frequency so that the antenna can radiate efficiently. There is a spacer between the antenna and EBG. Figure 4 shows there is a gap between the antenna and EBG structure which is maintained by using Rohacell 31HF (dielectric constant of 1.05). The novelty of this research is the gap which is supposed to be at $\lambda_g/4 \approx 7$ mm is reduced to 3 mm.

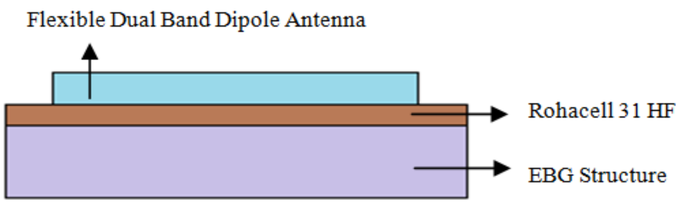


Figure 4. Flexible dual band dipole antenna with EBG structure

3. Results and Analysis

3.1. Flexible Dual Band Dipole Antenna

Return loss of flexible dual band dipole antenna is plotted in Figure 5. Simulated return losses of antenna are -21.24 dB and -15.18 dB at 2.45 GHz and 5.8 GHz respectively. There is shifted in resonance frequency during simulation but the antenna still performs well with -12.94 dB and -12.99 dB at both resonant frequency.

Then, an angular stability of the antenna is analysed where the performance under different angle of incident is evaluated as the flexibility of the structures are considered. Figure 6 plots the return loss of the antenna with different incidence angle. Noted that the antenna has high angular stability where different incidence angle does not affect the return loss of the antenna. The antenna structure has flexibility features with unlimited angle of bending.

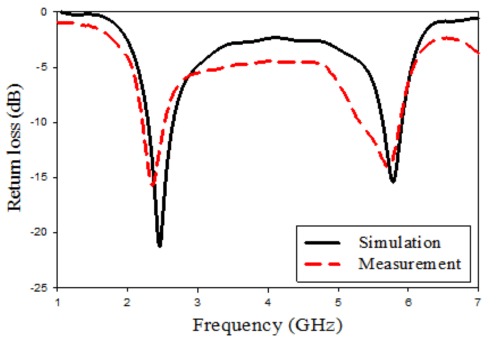


Figure 5. Return loss of flexible dual band dipole antenna

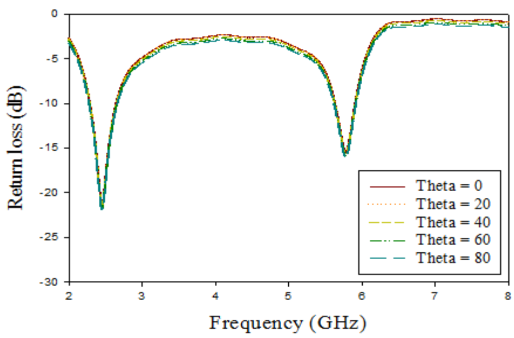


Figure 6. Return loss of flexible dual band dipole antenna at different incidence angle

Figure 7 shows the simulated radiation pattern of the flexible dual band dipole antenna. The antenna evaluates omni-directional patterns of radiation at both resonant frequencies. However the measured radiation pattern is slightly differ due to the uncertainty errors and cable losses during measurement. 1.83 dB and 4.17 dB of realized gain and 96.69% and 92.91% of total efficiency is achieved at 2.45 GHz and 5.8 GHz respectively.

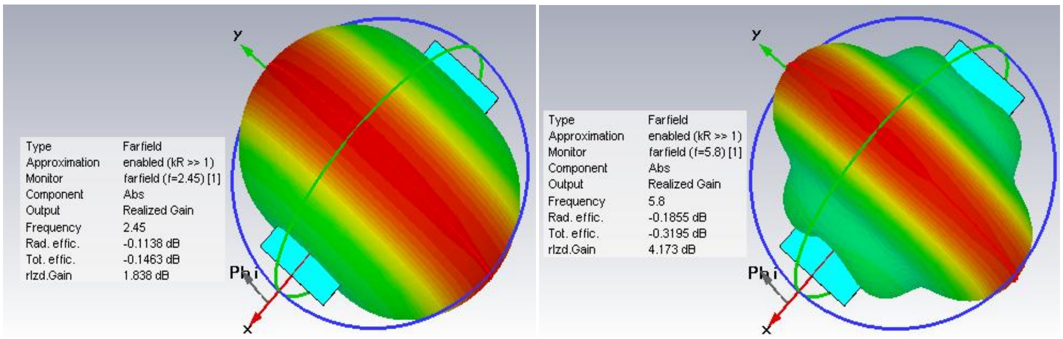


Figure 7. Radiation pattern of flexible dual band dipole antenna

3.2. Electromagnetic Band Gap

Figure 8 is the reflection phase and magnitude for a unit cell of EBG structure. Noticed that the reflection phase varies from +180^{o} to -180^{o}, at 5.8 GHz, the reflection phase is 0^{o} and at ±90^{o} reflection phase, the frequency is laid between the 5.70 GHz to 5.89 GHz. Thus contributes around 3.27% of bandwidth. While the reflection magnitude is -1.27 dB which is close to zero in order to be reasonably good ground plane for the antenna later on.

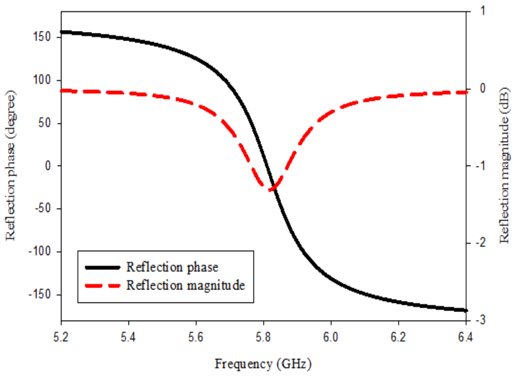


Figure 8. Reflection phase and magnitude of unit cell of EBG structure

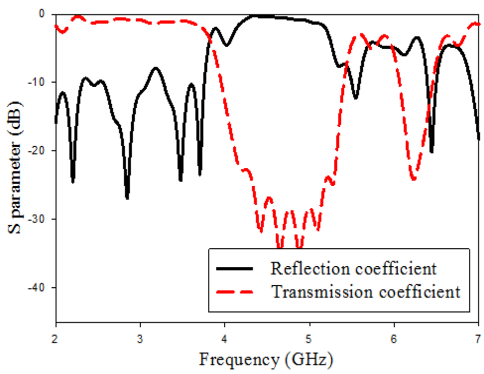
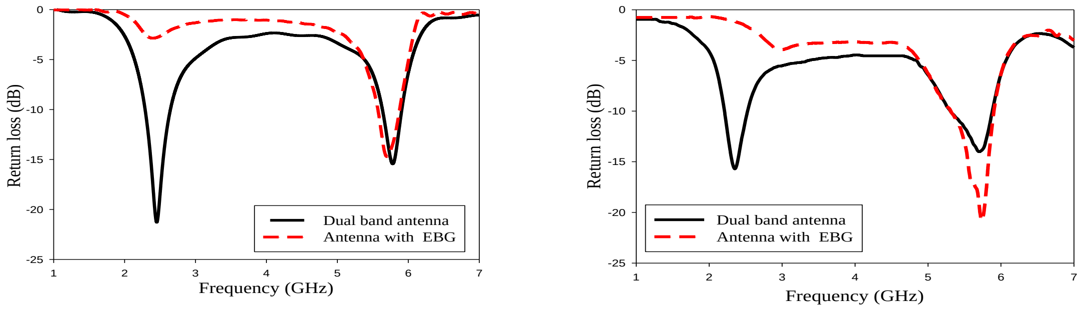


Figure 9. Transmission and reflection of the 5 by 2 EBG structure

Figure 9 shows the reflection and transmission coefficient (S_{21}) of the 5 by 2 EBG structure. The band gap of the structure is determined by the value of S_{21}. Based on -20 dB, the band gap frequency is between 4.11 GHz to 5.32 GHz and from 6.15 GHz to 6.32 GHz. Thus, 5.8 GHz is almost close to the occurrence band gap. The band gap is identifiedbyless than -20 dB of S_{21}in order to ensure that the entire surface wave signal radiates in this frequency band gap cannot propagate on the EBG structure. Therefore, the surface wave can be suppressed.

3.3. Flexible Dual Band Dipole Antenna with EBG

Figure 10(a) and (b) show the return loss of flexible dual band dipole antenna with and without the EBG structure by simulation and measurement respectively. Noted that the 2.45 GHz is eliminated and the 5.8 GHz resonant frequency is shifted as the antenna works with EBG. Despite the shift in resonance, the antenna still performs well with -12.94 dB and -17.75 dB of return losses by simulation and measurement. The EBG structure improves 0.44% of simulated bandwidth and 0.13% of measured bandwidth.



(a) (b)

Figure 10. Flexible dual band dipole antenna with EBG structure: (a) by simulation and (b) by measurement

Figure 11 illustrate the radiation pattern of flexible dual band dipole antenna with and without EBG structure at 5.8 GHz. The antenna alone has omni-directional radiation pattern initially becomes directive as it works with EBG. The front lobe is improved while the side and back lobes are clearly reduced. Antenna alone produces around 4.17 dB of realized gain while EBG helps to improve up to 6.86 dB by simulation while from 3.89 dB of realized gain up to 6.27 dB by measurement. However, the total efficiency of antenna alone is better than with EBG structure.

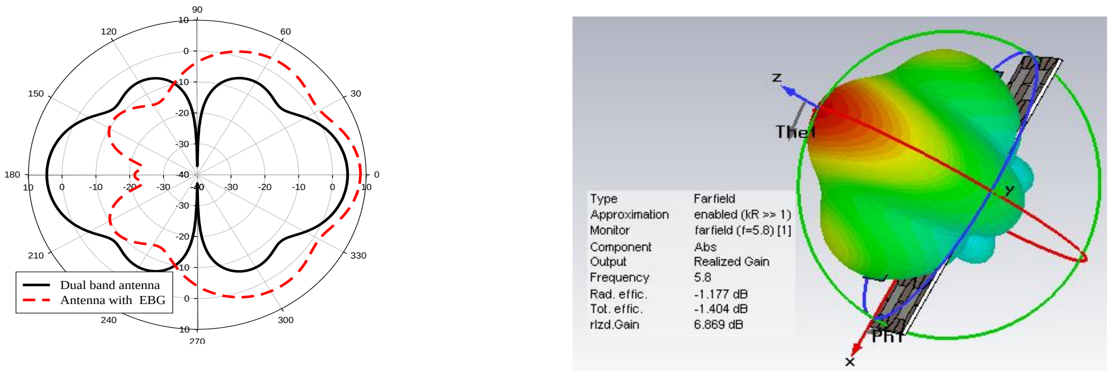


Figure 11. Radiation pattern of dipole antenna with and without EBG at 5.8 GHz

4. Conclusion

The bandwidth, gain and radiation pattern are successfully improved as the EBG structure is integrated with the flexible dual band dipole antenna. The radiation pattern of the antenna with EBG in term of front, side and back lobes are better as compared to the antenna alone. EBG works as a good ground plane for the antenna where the surface wave is suppressed in the frequency band gap. Besides, EBG also act as a filter as the resonant frequency of the antenna is out of the EBG band gap thus the current surface is allowed trough the EBG structure. The applications of the dipole antenna with EBG are Wifi and others on-body communication devices.

Acknowledgement

The authors wish to thank the Ministry of Science, Technology and Innovation (MOSTI), Center for Research and Innovation Management (CRIM) and also Zamalah Scheme of UniversitiTeknikal Malaysia Melaka (UTeM) for the support of this work under the grant number 06-01-14-SF0111L00019.

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