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Improving Parameters of Wearable Antenna Using EBG Structure

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Abstract: The wearable antenna plays a vital role in the wireless communication like Personal Area Network and Body Area Network. This is need of the hour to design a low profile, low cost, acceptable Specific Absorption Rate value, high gain, high directivity and power efficient wearable antenna for the mentioned fields of wireless communication. This paper presents an optimal solution to address the issues in the field of wearable antenna. The Electromagnetic Band Gap (EBG) structure has been integrated with the patch on the flexible substrate of polyurethane. Different parameters of wearable antenna have been improved using the EBG structure. Gain of this structure has been improved from 5.32dBi to 7.17dBi, directivity has been enhanced from 6.69dBi to 7.82dBi and efficiency has been increased from 69% to 88.87%. The results have been shown in detail in this paper.

Keywords: Return Loss, Bandwidth, BAN, Gain, Directivity, EBG and SAR

1. INTRODUCTION

In the recent era of wireless communication specifically the body centric communication, wearable antenna technology is getting more attention of consumers. The wearable antennas (on body antennas) are used in clothing materials and due to this technology cloths can sense and communicate. These antennas have wide range of applications from medical uses to military uses. Wearable antennas have special applications in various domains like Personal Area Network (PAN), Body Area Network (BAN) and they can also be used as Bluetooth antennas.

The wearable antenna can be constructed and fabricated easily and these antennas are cost effective as well. Due to the flexible nature of this antenna, it can be easily used in garments. Besides the advantages there are some disadvantages of the wearable antennas and the researchers have been working to rectify it. An antenna is used for the transmission and reception of electromagnetic waves between two stations. There are some hurdles in the efficient transmission of power from one place to another place. The disadvantages of the wearable antennas are low gain, power absorption by human body, the profile of the antenna and the compatibility of the wearable antenna with human body. The major problem of this technology is the compatibility of this antenna with human body because the nearness of human body to the radiating patch affects the performance of the antenna. Human body absorbs radiations and degrades the signals (Satheesh *et al.,* 2017) (Khaleel, 2014) (vsic *et al.,* 2018) (Chen, *et al.,* 2017) (Albert 2013). Using Electromagnetic Band Gap (EBG) structure the above mentioned issues of the wearable antennas can be addressed. EBG is repetitive structure which is helpful in suppressing or assisting of electromagnetic radiations in desired direction. The EBG structure also helps to stop radiations in the backward direction toward human body (Sangkil and. Yu-Jiun 2012) (Yook, and. Katehi, 2017). The SAR can be controlled due to this technique. The issue of SAR has been addressed in (Agaliya, *et al.,* 2016) with specific design of wearable antenna operating in ISM band as shown in **(Fig. 1).**

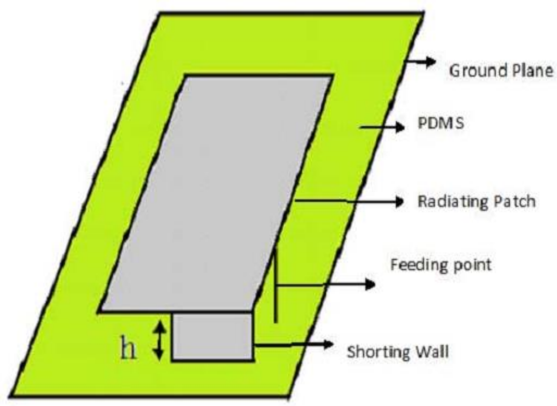

Fig. 1. The PIFA Antenna (Agaliya, *et al.*, 2016)

The SAR has been reduced to acceptable range using this method. But the problems of low bandwidth and detuning from the center frequency still exist in this design. **(Fig. 2)** shows the bandwidth and the detuning of frequency of the antenna.

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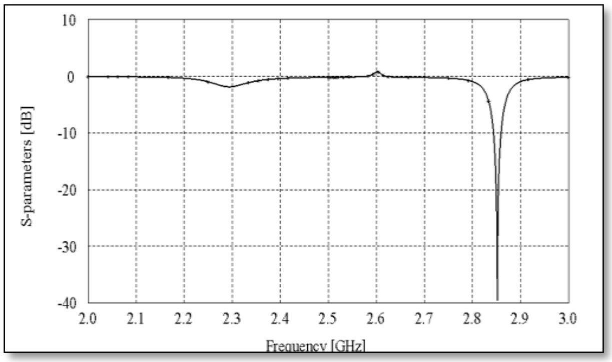

Fig. 2 S-plot of the Antenna (Agaliya, *et al.*, 2016)

The low gain and directivity are also the major issues of the wearable antenna in wireless communication. In article (Gil and Fernández-García, 2017) a wearable antenna has been implemented on fabric jeans for wearable applications. An extra substrate has been used to reduce the SAR value. The proper calculations of the exposure of human body to radiations need to be made in the fields of Wireless Body Area network, medical purposes applications and military applications. Some of standard organizations have addressed this issue and have found the safe and optimal value for SAR (Ziegel berger, 1998) Federal (Communications Commission Office 2001). Several factors affect the SAR value like intensity of radiations, frequency and source object orientation. The affect of radio waves on biological tissues has been reduced in (Merli, *et al.*, 2011) (IEEE Standard for Safety Levels 2005). The techniques used in this literature have also improved the gain and efficiency to some extent. But the problem of low bandwidth is still there in this research and needs attention. The bandwidth can be improved at the cost of other parameters like system complexity, degradation in gain and SAR (Majid, *et al.*, 2015).

2. ANTENNA DESIGN

The design of first basic wearable patch antenna, which is operating in ISM band is shown in **(Fig. 3).** The flexible substrate of polyurethane has been employed which has ε_r=3.56.

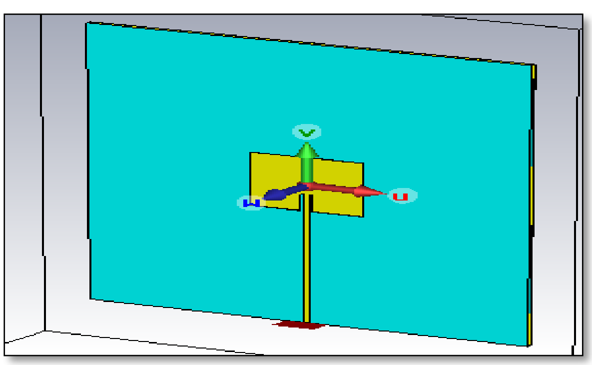

Fig. 3. Wearable Antenna without EBG.

After designing and simulating the wearable antenna without EBG Structure the wearable antenna with EBG structure has been designed and simulated. The dimensions of the unit cell of EBG are15.3×15.3 mm^2. Via having diameter of 0.5mm has been inserted to connect the patch of the cell to ground of the cell. The final design with human phantom shown in **(Fig. 4).**

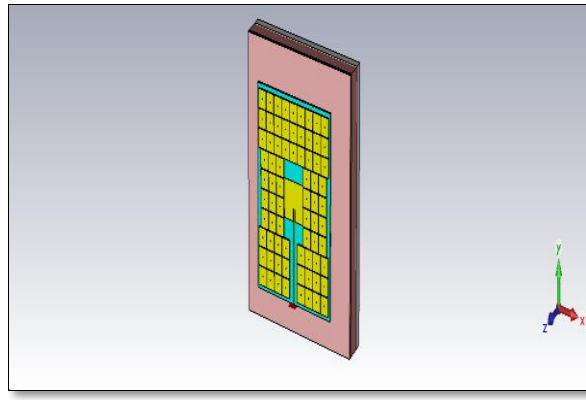

Fig. 4. Final design of antenna with EBG and Human Phantom

The summary of the parameters of the final design is given below.

Table 1: Summary of Dimensions of the Final Design

Dimensions	Values
Length of patch	31.7mm
Width of patch	38mm
Width of feeding line	2.032mm
Height of Substrate	2mm
Length of substrate	165mm
Width of substrate	146.8mm
Cell dimension	15.3×15.3mm^2
Cell’s Via diameter	0.5mm
Height of cell substrate	1.5mm
Distance of design from body	15mm
Gap between cells	0.5mm

3. RESULT AND DISCUSSION OF THE DESIGN WITHOUT EBG

The first design of wearable patch antenna without EBG structure was simulated and its results were observed. The result shows that the simple antenna has poor performance as it have low gain, low directivity, lower bandwidth and this design is less efficient. The results of these parameters are shown in **(Fig. 5, 6 and 7)** respectively. This design has demonstrated a gain of 5.32dBi, directivity of 6.69dBi and Bandwidth of 54.7MHz.

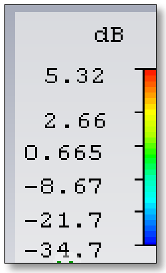

Fig. 5. Gain of Antenna without EBG

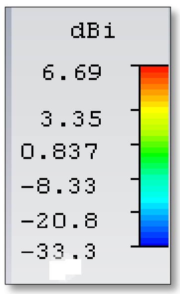

Fig. 6. Directivity of Antenna without EBG

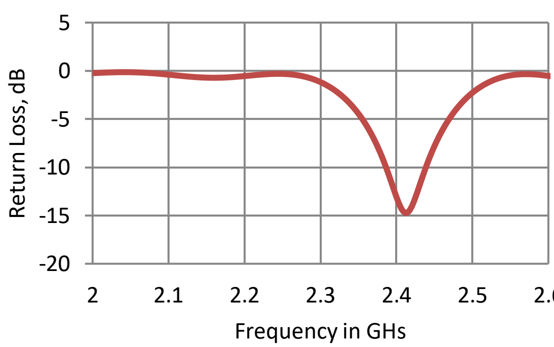

Fig. 7. S-plot of Antenna without EBG

VSWR of this wearable antenna without EBG structure is shown in (**Fig. 8**). VSWR is less than 2. Total Efficiency of this wearable Antenna without EBG is explained with the help of (**Fig. 9**). The maximum value corresponds to 2.4GHz and its value is 69.2%.

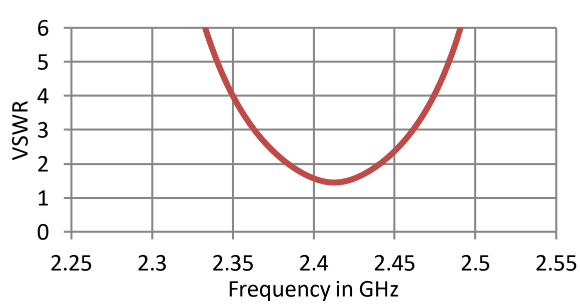

Fig. 8. VSWR of Antenna without EBG

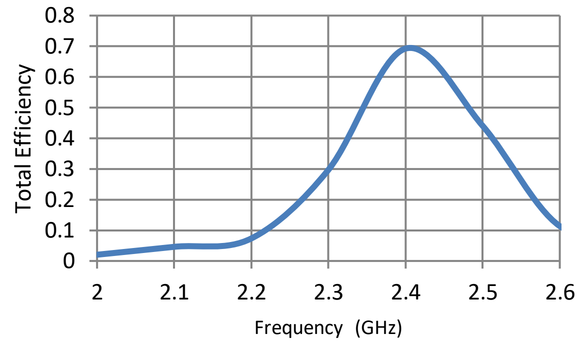

Fig.9. Total Efficiency without EBG

The Final antenna was integrated with EBG structure and its simulation has demonstrated an improvement in all the mentioned parameters. Directivity Gain and have been improved to 7.82dBi and 7.17dBi as shown in **(Fig. 10 and 11**) respectively. Table 2 displays the Directivity with EBG structure.

Table 2: Directivity of Final Antenna

Frequency(GHz)	Directivity (dB)
2	5.89
2.05	5.73
2.1	5.84
2.15	5.81
2.2	6.02
2.25	6.35
2.3	6.58
2.35	7.23
2.4	7.68
2.45	7.82
2.5	7.52
2.55	8.71
2.6	8.97

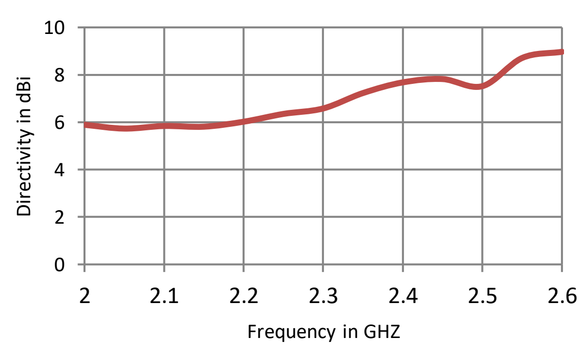

Fig. 10. Directivity of Antenna with EBG

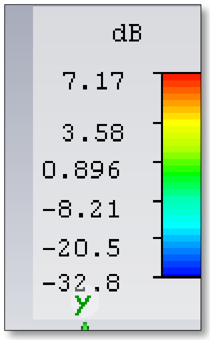

Fig. 11. Gain of Antenna with EBG at 2.4GHz

The problems of low bandwidth low efficiency have also been resolved up to some extent as shown in **(Fig. 12)** with slight detuning because of nearness of human body. The bandwidth is 64MHz and absorption rate of radiations by human body has also been reduced to an acceptable value of 0.0.093W/Kg as shown in **(Fig.13).**

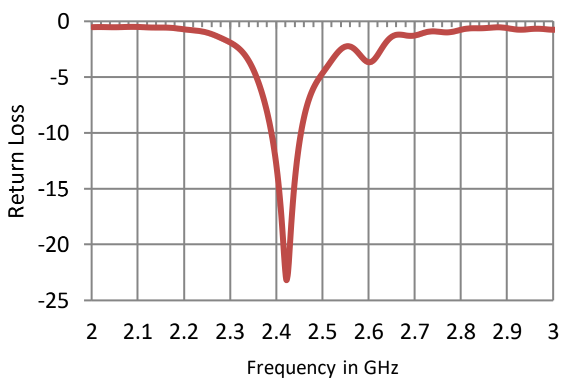

Fig. 12. S-plot of Antenna with EBG

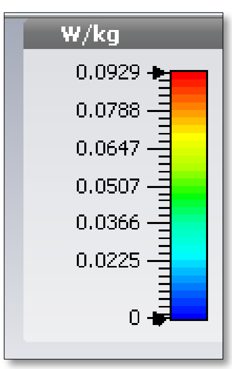

Fig. 13. SAR of Final design

The voltage standing wave ratio shows the optimal performance of designed antenna which is less than 2, as shown in (**Fig. 14**). The radiation efficiency of proposed design has improved to 88.87 % as shown in (**Fig. 15**).

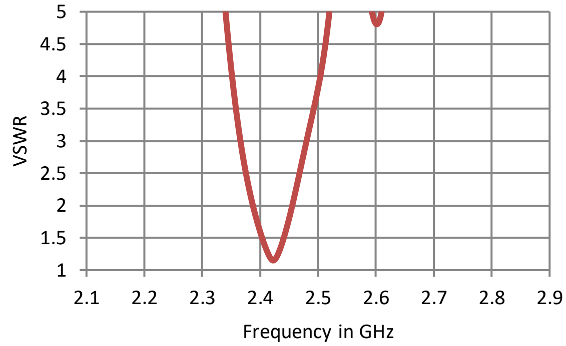

Fig. 14. VSWR of Final Design

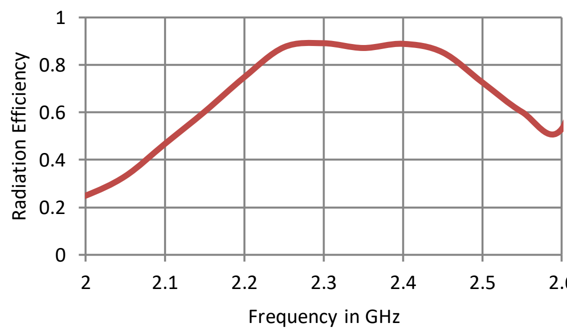

Fig. 15. Efficiency of Final Design

4. CONCLUSION

This research has addressed the limitations of wearable patch antenna which operates in the proximity of human body. An optimal solution of using Electromagnetic Band Gap (EBG) structure has been presented which is easy to fabricate and can be integrated easily with antenna. The mushroom like EBG structure has improved the parameters of wearable antenna. Specifically the gain, directivity, efficiency and bandwidth are improved. Bandwidth has been recorded as 64MHz. The SAR value has been brought to the acceptable range of 0.093W/Kg. Using this metamaterial, Gain of the antenna was improved from 5.32dBi to 7.17dBi, Directivity from 6.69dBi to 7.82dBi and the Total Efficiency from 69% to 88.87%. This wearable antenna can be used in ISM band.

REFERENCES:

Agaliya, T., M. Neebha and M. Nesasudha, (2016) "Efficient Wearable Antenna Design by Patch Area Extension for Body Area Network Applications. International Conference on Communication and Signal Processing, 6-8, India

Albert S, (2013) "Comprehensive Study of Printed Antennas on Human Body for Medical Applications", International Journal of Advance in Medical Science (AMS), Vol. 1, Issue 1, 1-10

Chen, S. J., T. Kaufmann, D. A. Chinthana, (2017) "Modular textile antenna design using snap-on buttons for wearable applications". IEEE Transactions on Antennas and Propagation, Vol. 20, no.10, 894-903

Federal Communications Commission Office (2001) of Engineering and Technology, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", Supplement C, 1–42.

Gil, I and R. Fernández-García, (2017) "Wearable PIFA antenna implemented on jean substrate for wireless body area network" Journal of Electromagnetic Waves and Applications, 05 1194-1204

Ivsic B., D, Bonefacic, and J. Bartolic (2018) "Considerations on embroidered textile antennas for wearable applications" , IEEE Antennas and Wireless Propagation Letter, t. 1650 -1653

IEEE Standard for Safety Levels (2005) with Respect to Human Exposure to the Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz. IEEE Std. C95.1..

Khaleel, H R, (2014) "Design and fabrication of compact inkjet printed antennas for integration within flexible and wearable electronics" IEEE Transactions on Components, Packaging and Manufacturing Technology, Vol. 4, no 10..1722 – 1728.

Merli, F., B. Fuchs, J. Mosig, and A. Skrivervik, (2011) "The Effect of Insulating Layers on the Performance of Implanted Antennas," IEEE Transactions On Antennas and Propagation, vol. 59, no. 1, 21–31/

Majid,H., Abdul Rahim, M., Hamid, M,. Yusoff, M,. N Murad, N,. Samsuri, N,. Ayop, O,. Dewan,R., (2015)" Wideband Antenna With Reconfigurable Band Notched Using EBG Structure", Progress in Electromagnetic Research Letters; 54: 7-13.

Majid, H., M Abd Rahim, M Hamid, M Yusoff, N Murad, N Samsuri, O Ayop, R Dewan. (2015) "Wideband Antenna With Reconfigurable Band Notched Using EBG Structure", Progress in Electromagnetic Research Letters.54: 7-13.

Satheesh B. R., M. P. Jaya, K. P Mohanan and K. P. Surendran, (2017) "Design and fabrication of an E-shaped wearable textile antenna on PVB-coated hydrophobic polyester fabric", Smart Materials and Structures, Vol. 26. article id. 105011.

Sangkil K., R. Yu-Jiun (2012) "Monopole Antenna with Inkjet-Printed EBG Array on Paper Substrate for Wearable Applications". IEEE Antennas And Wireless Propagation Letters, Vol. 11. 663-666

Yook, J. G., L. Katehi, (2017) "Micromachine dmicrostrip patch antenna with controlled mutual coupling and surface waves". IEEE Transactions on Antennas and Propagation, 2001, vol. 49, no. 9, 1282-1289.

Ziegelberger, G. (1998) "ICNIRP GUIDELINES for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz),"Health Phys., vol. 74, no. 4, 494–522.