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Planar Monopole Antenna with Compact EBG For Wireless Body Area Network (WBAN) Applications

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Abstract*: The letter presents a planar antenna backed with an EBG structure. The properties of the EBG have been studied and obtained efficient radiation of an antenna which is used for wearable applications. The gap that separates the ground and the EBG layer is varied due to which the antenna radiates at 2.48 GHz. The prototype models of antenna show measured gain of 6.5 dBi with the EBG structure on the background. The proposed prototype is fabricated on a 30 x 20 x 0.7 mm3 denim substrate has dielectric constant of 1.7mm as its property. Detailed analysis of the prototype and results exhibited for various cases are shown, and in all conditions the antenna withholds its performance. The efficient radiation patterns, high gain and compact size makes the proposed antenna a worthy choice for wireless body area network communication.

Index Terms: **Electromagnetic Band Gap (EBG), Wearable Antenna, Wireless Body Area Network (WBAN).**

I. INTRODUCTION

Wearable antennas are a new emerging technology with several applications like wireless telemetry, health care monitoring, tracking and implantable applications. which can be used along with an Electromagnetic Bandgap (EBG) structure to obtain a compact and robust antenna with high gain and efficiency. EBG structure can also be used as an isolation of the antenna from the person as the radiation of antenna can affect the human body and the antenna efficiency may also be affected due to the proximity with the human body [1]. Electromagnetic band-gap (EBG) is a structure which helps to create a stopband. It helps to hinder the electromagnetic waves of certain frequency bands. It is accomplished by constructing a periodic pattern of small patches on dielectric substrates [2]. At the same time, the EBG structure reflects the EM waves of different frequency bands which are detected and receives them at a high sensitivity. There are several designs presented in the open literature, a slot antenna is proposed for medical requirements. The characteristics of the body-area networks is an active area of research and they are calculated using the FDTD method [3]. Properties of on-body propagation is explained with the help of a couple of microstrip patch antennas required for various links and the efficiency of potential radio systems is investigated [4]. A broadband wearable PIFA antenna designed for WBAN applications is discussed. Flexible copper foil, Shield It Super and pure copper polyester taffeta conductive textile materials are considered [5]. A compact conformal wearable antenna with a highly truncated meta surface is considered. It consists of an array I-shaped element [6]. A novel EBG structure is designed with a single-ring resonator is printed with the help of an ink-jet printer on a photo paper by conductive Nano-silver ink [9]. A novel UWB antenna is described here. The structure consists of two patches and a ground plane which is implemented. The full ground plane on the lower layer shields users against on-body radiation [14]. An antenna which is wearable and dual-band magneto-electric is explained in this letter. U-shaped slots are etched on an antenna which is dipole to produce a dual band characteristic. The antenna is constructed using wearable materials [15]. A dual-band antenna is introduced using brass eye-lets. A waveguide cavity with ground plane and a half-mode substrate is realized and it is compact and conformal and directs the radiation away from the person who is sporting it [16]. A low-profile antenna integrated with EBG which consists of rectangular structures for medical applications is put forward in this letter. The main objective of the design is to reduce the back radiation EBG structure is used with which the gain of the antenna is also increased. Antenna and EBG design, parametric analysis, results and analysis and the conclusion is given in the subsequent sections which are sections 2,3,4,5.

II. ANTENNA AND EBG DESIGN

The proposed antenna is achieved with the help of following iterations as delineated in figure 1 and the outcome is shown in figure 3. The iterations have a patch with the dimensions of 20×16 mm and has a substrate of denim. It has a height of 0.7mm with dielectric constant of 1.7 and loss tangent of 0.02. First, a basic rectangular patch antenna is designed and for the second iteration a slot of 4.9 mm length is considered on the upper part of the rectangular patch. For the next iteration two slots one at the top of the patch and other at the lower part of the patch each of 4.9 mm length is taken. Finally, after introducing a small part to the patch the output which is desired and required for the ISM band applications is obtained. It is coplanar waveguide fed antenna which is resonating frequency of the antenna is 2.48GHz with the applications of wearable body area networks (WBAN). Table 1 depicts the antenna parameters.

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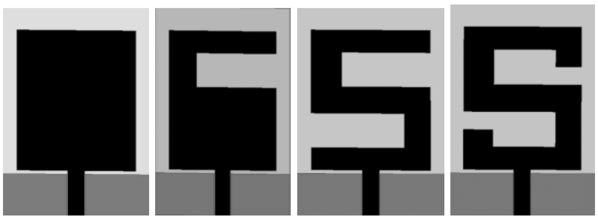
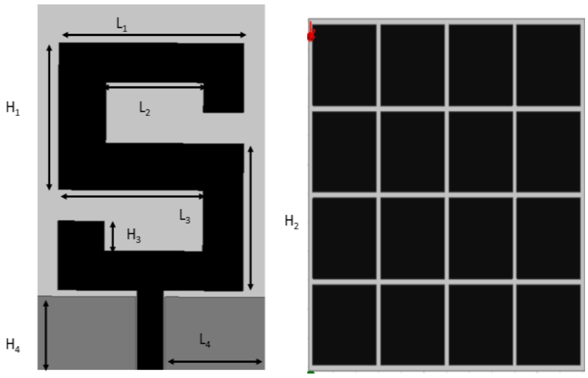


(a) (b) (c) (d)

Fig 1. (a) Iteration1(b) Iteration 2(c) Iteration3(d) Proposed Antenna.

A. EBG Design

An EBG is designed which is compact as well as robust which suits the proposed antenna is shown in figure 2(b). A square of width 14.0 mm is considered and the separation between them is 1mm. The squares are placed on a denim substrate of dimensions 60.5×60.5×0.7 mm^3. EBG is placed at 25mm from the antenna.



(a) (b)

Fig 2. (a) Proposed antenna (b) EBG introduced for the proposed antenna

Table 1. Parameters of the antenna

Parameters	Value (mm)
H_1	11.9
H_2	11.5
H_3	2.4
H_4	6.1
L_1	16
L_2	8.4
L_3	12.5
L_4	8.75

III. RESULTS AND ANALYSIS

The performance of the iterations of the antenna is laid out in the figure 3. For first iteration, the antenna radiates barely at 4.3 GHz. So, the second iteration is considered where the output obtained is at 3.2 GHz and the output is not so desirable. For the third iteration the output obtained is at 2.6 GHz which does not hold the applications which are required. The proposed antenna it covers the wireless body centric application for all medical and ISM band frequencies.

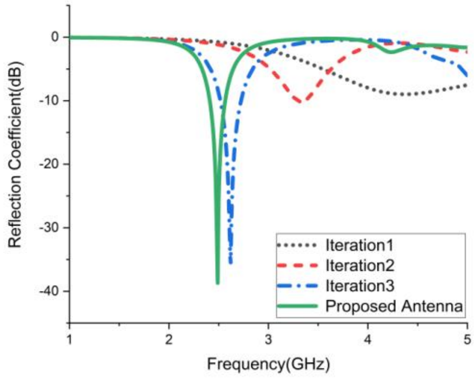


Fig 3. Reflection Coefficients of iterations and the proposed antenna.

A. Parametric Analysis

In the following section, the parametric analysis of the prototype is discussed. In figure 4, the width of the slot (a_1) is varied from 2.2 mm to 2.4mm at an interval of 0.1mm. When the width is 2.4mm the output obtained is not desirable as it does not have the applications which are considered to design the antenna. The output obtained at 2.3mm is better compared to 2.2mm and it also satisfies the required applications.

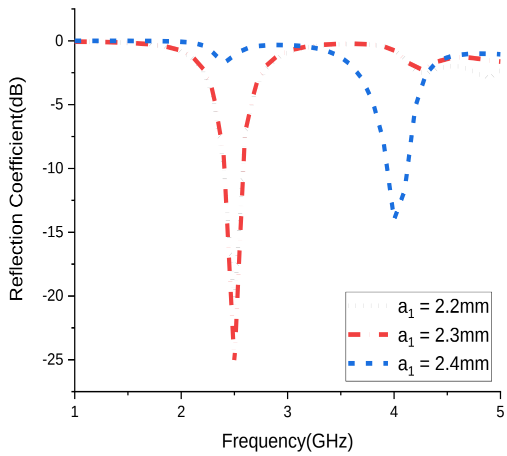


Fig 4. Parametric analysis for varying the a_1.

Next the parametric analysis is considered for length of the patch (L1) from 13mm to 17mm at an interval of 1mm in the figure 5. The best and required output is obtained for the length of 16mm than for the other lengths considered. When the length is considered as 17 mm the operating frequency is obtained at 3GHz, which is not the application for this letter aiming. The output obtained for 13mm,14mm and 15mm lengths obtain the required application but when the length is 16mm the antenna radiation is desirable.

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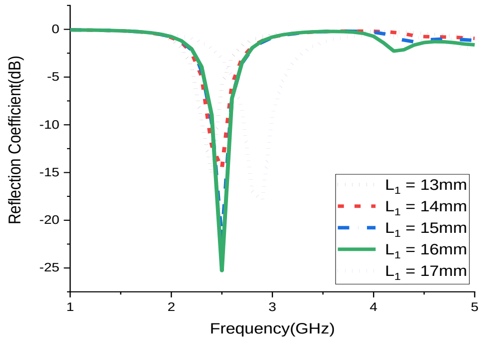

Fig 5. Parametric analysis for varying the L_1.

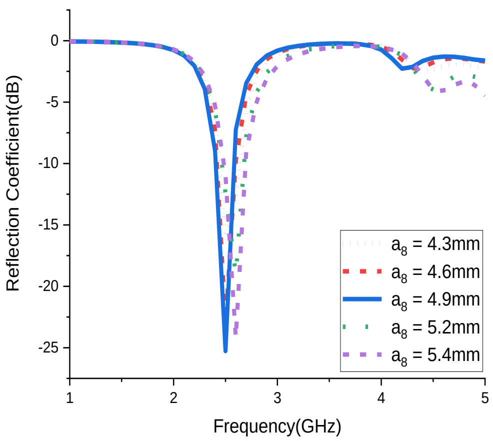

Fig.6 Parametric analysis of varying the a8

In the figure 6, length of the feed (a8) is varied and the desired output and the result which satisfy the application is obtained at 4.9mm. But there is not much difference in the results obtained for the lengths 4.3mm,4.6mm,5.2mm and 5.4mm. But the antenna radiates a little bit more at 4.9mm compared to others difference is not noticed. So, this parameter has least effect on the outputs obtained for the antenna.

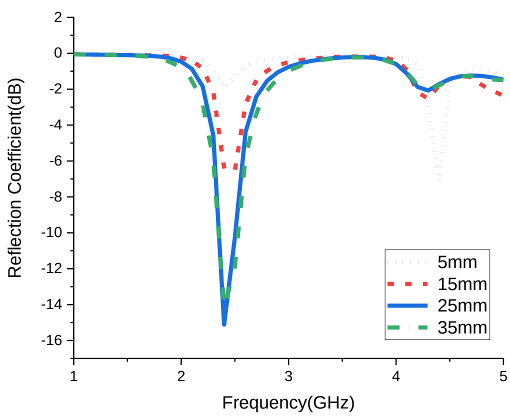

Fig. 7. Parametric analysis of distance between antenna and EBG.

In figure 7, the analysis is exhibited when the separation between the antenna and its EBG is varied. When the distance between the antenna and EBG is 25mm the result obtained is desirable when compared to the other distances. There is not much difference of outputs at 25mm distance and 35mm distance, but the least distance is considered, and the antenna radiates a bit more for 25mm. While when the distance between antenna and EBG is 5mm or 15mm the antenna does not radiate at all.

B. Reflection Coefficient with and without EBG

In figure 8, presents reflection coefficient for the antenna excluding EBG and the reflection coefficient of the antenna including EBG is compared and the resonating frequency is obtained at 2.48GHz which covers the Wireless Body Area Network (WBAN) applications. By placing the EBG structure on below the radiating patch the variations are observed in the S_{11} but here is no much variation in the resonating frequency.

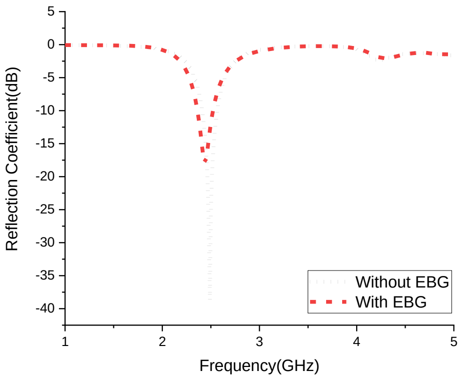

Fig 8. Proposed antenna Reflection Coefficient without and with EBG

C. Peak Gain

The peak gains of the antenna without and with EBG are compared as shown in the figure 9. The antenna shows the gain of 2dBi without EBG. The main reason to introduce the EBG is to increase the gain. And the change can be observed in the figure where for the antenna with EBG the peak gain shoots to 6.5dBi. Even the radiation pattern of the antenna has focused towards the forward direction which has improved the gain characteristics of the antenna.

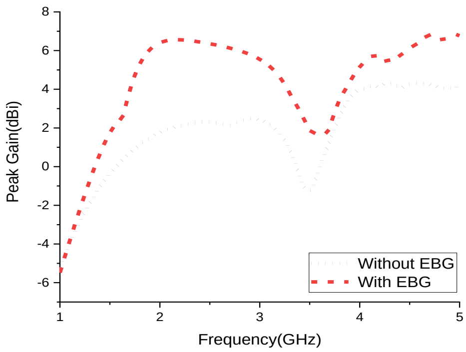

Fig 9. Proposed antenna Peak gain without and with EBG

D. Radiation Patterns

The patterns for the antenna without EBG and antenna with

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EBG are compared in the XZ and YZ planes in the figure 10(a) and 10(b). The radiation pattern for the antenna without EBG in XZ direction is omnidirectional whereas for the antenna with EBG the pattern is mostly in the forward direction which signifies that the radiation on the human body decreases when the EBG is introduced which decreases the radiation in z direction due to which the radiation on human body reduces which is the main requirement of the wearable antenna. The radiation pattern for antenna without EBG in YZ direction is bidirectional in the XZ direction it concentrates more in forward direction.

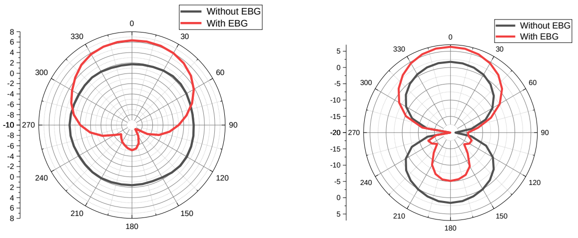
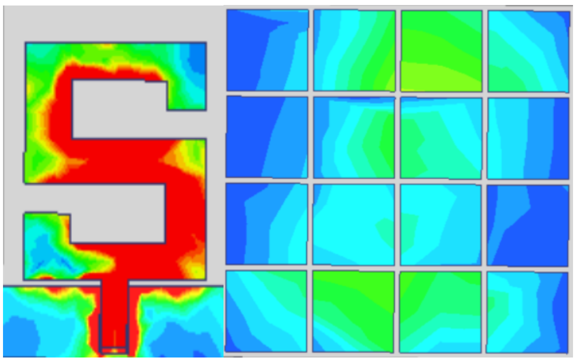


Fig 10. (a)Proposed antenna radiation pattern in XZ direction (b) Radiation pattern in YZ direction

E. Current Distributions

The current distribution on the antenna and EBG is presented in the figure 11(a), 11(b) and 11(c). The current distribution in the antenna is very high at feed line and a part of the ground which is adjacent to the feed line. And as the antenna is attached to the feed the distribution follows the shape of the antenna and the current density reduces in the antenna the farther away it is from the feed. The current distribution in the EBG is high in most of the elements which are present in the EBG.



(a) (b)

Fig 11. Current distribution of antenna and EBG (a) Current distribution in antenna (b) Current distribution in EBG

(a) (b)

Fig.12 (a) Measured results of the antenna (b) Fabricated Antenna.

Table 2. Comparison of the proposed antenna against other EBG or AMC backed planar antennas

Reference	Dimensions (mm × mm)	Operating Frequency (GHz)	Gain (dBi)
[7]	150×150	2.45	-
[8]	120×120	2.45	6.4
[10]	127×87	2.45	0.86
[11]	110×130	2.45	-
[12]	100×100	2.45	4.0
[13]	65.7×65.7	2.45	4.8
Proposed antenna	60.5×60.5	2.5	6.5

The measured results provide the coincidence with the results obtained by Ansys HFSS and the fabricated protype of the antenna is presented in Figure 12. The comparisons of different designs are presented in the table.2 where the gain of the antenna is high and compact in size.

IV. CONCLUSION

A compact and robust wearable antenna is fabricated and tested in this letter. The designed antenna is of the dimensions 60.5×60.5×0.7 mm^3 with a peak gain of 6.5dBi and the antenna radiates at 2.5 GHz which is ISM band. The proposed antenna is very compact and exhibits good gain compared to most recent configurations as listed in the table 2. The antenna designed is used in medical applications. The main purpose this antenna is designed for wireless body area network (WBAN)communications which is a medical application. The antenna can be placed in contact with the human body or can be introduced on the human body without any effects caused by the proposed antenna to human body and can obtain the readings in the body and transmit signals.

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