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Electromagnetic Band Gap Based Via-less Jeans Patch Antenna for 5.5GHz WiMAX Application

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Highlights

- The focus of this paper is on the design and analysis of Jeans based textile patch antenna.
- The electromagnetic Bandgap Structure was designed and analyzed based on its parametric analysis.
- The electromagnetic Bandgap improved the performance of an antenna.
- Design of textile patch and Bandgap structure successfully obtained from the simulation.

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Abstract

Wearable electronics have gained opportunities in recent years, and the last decade has been evidence of this growth in Wireless Body Area Networks (WBAN). They meet the criteria for personalizing healthcare, communication, patient monitoring, tracking, and rescue operations. The main challenge for the WBAN is to handle the radiator's coupling with the human body. An artificially generated Electromagnetic Band Gap (EBG) structure was designed and used in this work to improve the performance of a microstrip patch antenna. A jeans-based microstrip patch antenna with an EBG surface demonstrated to enhance the performance for 5.5 GHz WiMAX application. The use of an EBG surface increases return loss by 20%, with a reasonable bandwidth of 0.528 GHz (5.271 GHz to 5.749 GHz) at the resonance frequency of 5.5 GHz. The EBG surface improved the Voltage Standing Wave Ratio (VSWR) by 60%. A three-layered human body tissue model is also used for on-body measurements to determine the performance of an EBG-based antenna. The presence of human tissues generally reduces performance and shifts the resonance, but the shifting in this work with the simplified EBG structure and adequate gain and VSWR is only 2.6 percent.

1. INTRODUCTION

Researchers are becoming interested in wearable and textile electronics. It has a huge potential to improve our lives. The mechanical features of electronic devices, such as wrinkles, bends, and stress, play a vital role when textile and flexible electronics are placed on or near the human body. The future generation of consumer electronics should be characterized by low-cost manufacturing, inexpensive, flexible, widely available substrate, lightweight, and easy to design and assemble. Antenna sensors are commonly utilized in these applications because they can perform passive operations, multimodality sensing, and low-cost transmission. Some sensors could communicate as well as sense, and their implementation may mandate the usage of as few components as possible. With the effective use of the flexible/wearable system in the application, the textile must be chosen in such a way that it can be readily incorporated into the clothes. The implantable wideband biocompatible antenna is also designed for standard ISM band applications for medical purposes. The author has implemented the compact antenna inside the human body voxel model and a good agreement of Specific Absorption Rate (SAR), return loss, and other performance parameters have been simulated and measured [1]. The SAR is a measure of the rate at which energy is absorbed per

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unit mass by a human body when exposed to a radio frequency (RF) electromagnetic field. Federal Communications Commission (FCC) limits the set on SAR with 1.6W/kg averaged over 1 gram of actual tissue. The SAR limit recommended by the Council of the European Union is 2.0W/kg averaging over 10 g of actual tissue.

Despite the proximity of the wearable patch antenna, one of the most important functions of such body-worn devices is to minimize the antenna's interaction with the human body. When the human body is subjected to such radiations for an extended period, the human tissues may be damaged, which lead to major health problems in the long could term [2]. Researchers have expressed their opinions that the effects of radiations on the human body should be taken seriously [3-5]. There are two types of wearable microstrip patch antennas one which is entirely textile and the other one is partially textile. When considering entirely textile antennas for WBANs, the radiator patch's coupling with the human body must be regulated, as this becomes a key source of radiation absorption. Planar patch antennas, on the other hand, have several disadvantages over non-printed antennas, including a very narrow bandwidth, poor or very low radiation efficiency due to surface wave excitation across the patch, low gain, and so on [6–10].

Many strategies and techniques are being used in the literature to overcome the restrictions. The bandwidth was increased by stacking ferrite material on top of the thick, low-permittivity substrates, but the cost increased as a result. Although non-contact feeding increases bandwidth, it complicates fabrication, as documented in the literature [11, 12].

The array positioning of the patch antenna could boost the gain. The array-loaded patch antenna has a substantial problem due to surface wave generation caused by nearby array elements. The array design becomes significant when the permittivity (substrate), thickness, and operating frequency are all higher resulting in this coupling effect. The connection between the pieces can sometimes cause a blind area. The spacing between connected patch elements can be widened to alleviate this, but these results in grating lobes in the radiation pattern. The radiation efficiency and gain of directional antennas are reduced by grating lobes [13-15].

The difficulty for wearable antennas is to reduce the back radiations, while simultaneously improving the antenna's performance. A "Metasurface" is a manufactured structure that can be utilized as a band stop or bandpass surface when used in conjunction with a patch antenna.

The Metasurface designed in this paper uses the parametric analysis on unit cell structure. The stopband was acquired to stop the back radiation after the parametric analysis on the Unit EBG Cell. Now, depending on the application, the newly developed device might be installed beneath the antenna to act as a band stop or bandpass filter. In this study, the patch is used in the 5.5 GHz Worldwide Interoperability for Microwave Access (WiMAX) band and the antenna with and without an AMC surface is compared. The fabric used in this project is a relatively popular jeans fabric, and the conducting substance is copper tap, which adheres to the jeans readily.

This full-textile antenna is developed with the simplest EBG for WiMAX applications at 5.5 GHz. The most exciting element of this paper is that the EBG reduces back radiation while increasing gain with a best VSWR value below 1, which has yet to be demonstrated by any previous work [16-22]. Most of the literature focused on Via’s architecture to regulate the Bandgap feature; they did so use a complicated structure that can improve the effective inductance as indicated in the literature. As a result, a basic patch is built and simulated for parametric analysis in this article, along with a noncomplex EBG structure. The EBG and patch antennas are not complicated, and with the simplest design structure, they produce better results than the complex EBG-based patch antennas reported in the literature [18, 23-25].

In section 2, the dimensions of a jeans-based textile patch antenna are estimated and optimized to provide the necessary band of operation. In section 3, the EBG structure was introduced, and parametric analysis has been performed on the unit EBG cell to increase the performance of the reference antenna in the same range of applications. The experimental results and explanation of the patch antenna with and without the EBG structure are shown in Section 4.

2. DESIGN AND ANALYSIS OF TEXTILE MICROSTRIP PATCH ANTENNA FOR WiMAX

The ISM band (Industrial, Scientific, and Medical) can be utilized as low-cost radio communication and design. In addition to communication, it is utilized as real-time patient monitoring and position tracking. The Federal Communication Commission (FCC) recently designed and presented the "Medical Body Area Network" (MBAN) as a new frequency band (2.36 GHz to 2.4 GHz). WBAN and PAN (Personal Area Network) are two more wireless networks, which are often used for low-range wireless networks that allow electronic devices to operate near the human body [26].

The 5.5 GHz frequency, which is utilized for WiMAX, is also one of the most popular bands. This is also crucial in our life since it makes things easier. The demand for body-centric communication is rapidly increasing, prompting advancements in the field of wearable flexible electronics. According to researchers, the possibilities for body-worn wearable antennas that might be easily integrated into a wearer's garments are endless.

As dielectric substrates, textiles such as denim, washed cotton, Lycra, polyester, poly cot felt, woolen, fleece, silk, Velcro, and nylon are used. These materials are inexpensive and readily available. Flectron, Pure Copper Taffeta, Shieldit, and Zelt, among others, are the most used conductive fabrics in literature for the antenna's conductive sections. In this work, the typical jeans cloth is used as a substrate, with conductive components made from copper adhesive tape. The following formulas are used to calculate the patch dimensions.

Calculating the width of the main patch/radiator (W):

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{(\epsilon_r+1)}} \quad . \tag{1}$$

Calculating the effective dielectric constant (ϵ_{reff}):

$$\epsilon_{reff} = \frac{(\epsilon_r+1)}{2} + \frac{(\epsilon_r-1)}{2}\left(1+\frac{12h}{w}\right) . \tag{2}$$

Calculation of the length of the main patch/radiator (L):

$$L = \frac{c}{2f_r\sqrt{\epsilon_{reff}f}} - 2\Delta L , \tag{3}$$

$$\Delta L = 0.412h\left[\epsilon_{reff}+0.3 \Big/ \epsilon_{reff}-0.258\right]\frac{\frac{w}{h}+0.264}{\frac{w}{h}+0.8} \quad , \tag{4}$$

Length of the feed line (L_f):

$$L_f = \frac{\lambda g}{4} \ . \tag{5}$$

The calculated values are optimized for the desired band of operation, and then we get the width of patch W= 23.9 mm, length of the patch L = 20 mm, and jeans substrate layers will be used to combine into a thickness of t = 2.5 mm. There are many techniques available that are used for the excitation of energy. The most easily designable and common one is inset feed, so to feed the energy in the patch inset feeding method is used in this work. For that the feed line length L_f = 11.13 mm, the width of the feed line W_f = 6.5 mm, and the gap g =1 mm as shown in Figure 1(a). The generation of fringing fields because of the presence of perfect electric conducting ground structure in the bottom part of the dielectric substrate shown in Figure 1(b).

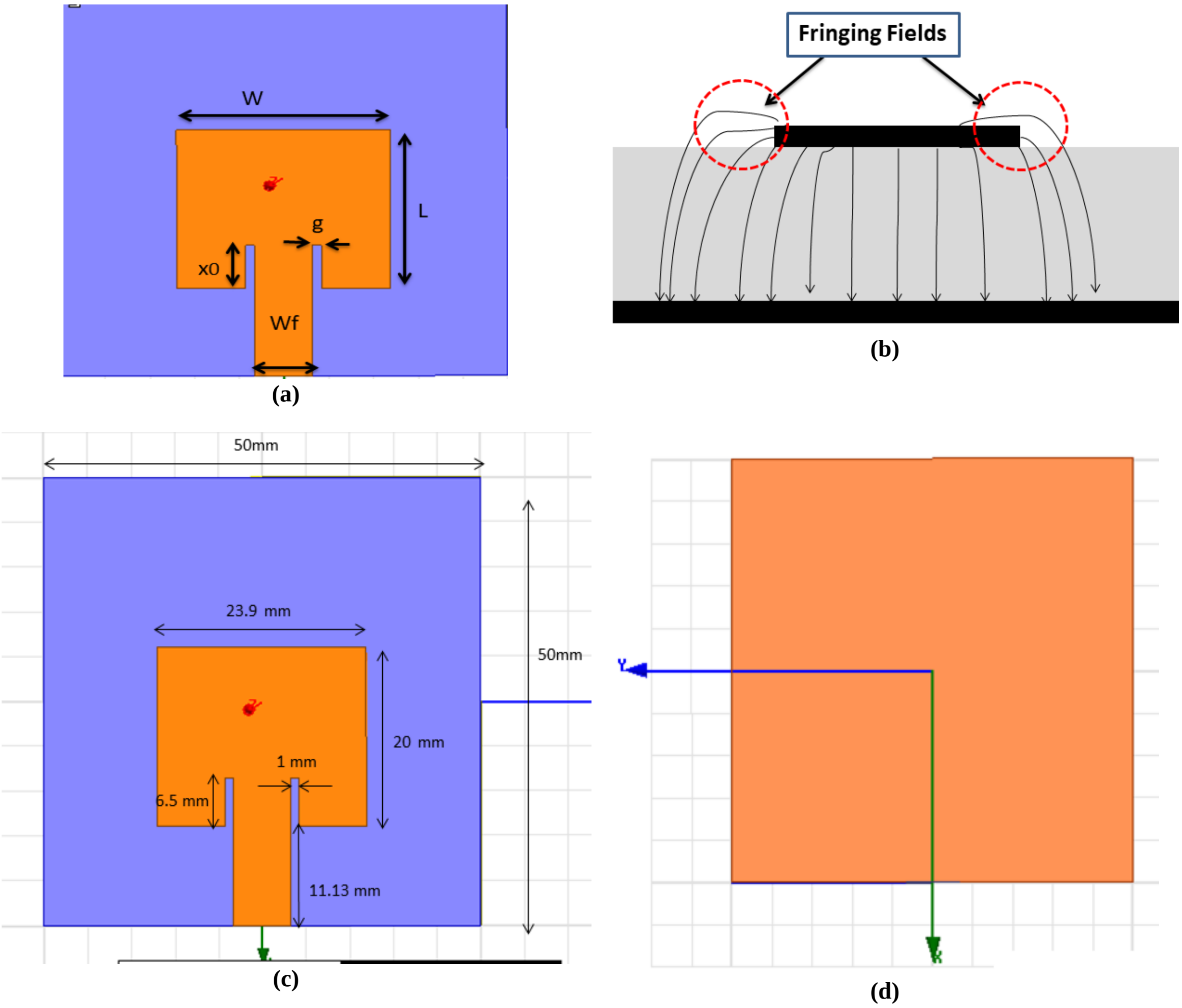


Figure 1. *a) Basic Patch antenna with calculated dimensions b) Radiated fringing fields from the patch radiator to till the ground c) Jeans based patch antenna-front view, d) Back view*

These fringing fields cause losses in the structure because some of the field radiation is reflected back to the ground through the dielectric substrate. As a result, the overall radiation in the far-field radiation pattern is reduced. This work is on textiles and will be worn on the human body, so its prime purpose is to make the process easy. Same time to make the radiation more confined in a single direction the back radiation must be reduced so it will not harm the human body tissues by absorbing the radiation. The front view design of the reference patch with all calculated dimensions is shown in Figure 1 (c) and (d) show the patch's backside as a ground.

2.1. Selection of Textile Material for Wearable Antenna

Portable electronics are ushering in a new era of electronics, and smart fabrics are transforming the evolution of modern communication. According to the various literatures, the term "smart" refers to the ability of the material to communicate, read, receive, and sense information [27-31].

This material is hybrid of electronics and textile structures, also known as an e-textile or electronic textile. When the textile is used as the smart device structure, several challenges must be mitigated, such as the loading of the human body near to the radiator, generation of surface waves, which reduces the performance of the system. The need for a long-lasting smart conducting fabric arises because conventional rigid materials are rigid, inflexible, and non-deformable.

There are two textiles used for patch antenna design. One is a conducting textile used as the conductive patch/radiator and ground. The other textile is a non-conductive textile used as a substrate. The microstrip patch antenna geometry was identified as the most adaptable to wearable and smart clothing because it is low-profile and flexible in this case [32-35].

Planar microstrip patch antennas consist of ground and a patch made of conductive textile and a substrate covered with electrically insulating textile. In this work, the fabric material jeans, with a permittivity of 1.7, loss tangent of 0.085, and a thickness of 2.5 mm, are used as a substrate by putting layers of jeans together to increase the thickness of the substrate. For the conductive part, the copper tape is preferred because of its ease of fabrication.

2.2. Design of Jeans Patch Antenna and Analysis

The Patch antenna is optimized and designed to get better performance for the resonance frequency of 5.5 GHz. The Jeans substrate, with a dielectric constant of 1.7, a thickness of 2.5 mm, and a loss tangent of 0.085, is used as the non-conductive part of the textile antenna. The conductive part is designed using copper tape having a thickness of 0.035 mm, which makes the fabrication process easy and cheap. The substrate and conductive materials is textile, so the designing process becomes challenging. The conventional microstrip fed rectangular patch antenna is chosen as the patch's most simplified design. As a result the finally selected design for the textile patch should be easy to fabricate.

3. DESIGN METHODOLOGY OF THE EBG UNIT CELL AND ITS PARAMETRIC ANALYSIS

The property of EBG is not the natural property of any material, but artificially this could be formed to get the desired operation, whether it is a bandpass or band stop. The concept behind the design of this EBG surface is the property of a High Impedance Surface (HIS). This EBG prevents the surface wave when two dissimilar mediums are used for electromagnetic wave propagation. The major property of the HIS is that it creates the conducting surface in the patch antenna designed and simulated in much literature.

In this paper the concept of band stop is used for the desired resonance frequency in which the patch/radiator is radiating energy in a positive z-direction. Because the TM (Transverse Magnetic) wave can only propagate on an inductive surface and the TE (Transverse Electric) wave can only follow the patch of a capacitive surface, therefore it is now necessary to design a surface structure that possesses the properties of both surface impedances at the same time. So, the capacitive and inductive impedances are the key points of the EBG surface. This could be understood as an LC equivalent circuit, which prevents the surface wave in a specific range of frequency. This periodic structure could be designed and analyzed by starting with a single unit cell design of the EBG structure.

A periodic structure is obtained by connecting the two-port networks in a case-cade fashion. These models usually consist of the properties of inductors and capacitors, presenting a high impedance surface for a certain range of frequencies. The structure is designed and simulated by using a unit cell. Based on the performance of this unit cell, the property of the complete structure is decided. The design of the unit EBG cell takes two steps. In the first step need to use Sievenpiper’s equation and the next step is to use the simulator, here used the Ansys HFSS [36] simulator for optimization on the calculated values. There is no direct formula for the precise designing of a unit cell, but the impedance nature of the unit EBG cell designed by using the Equations (6), (7), and (8) these are known as Sievenpiper's Equations

$$L = \mu_r \mu_0 h \tag{6}$$

$$C = \frac{W(\varepsilon_1 + \varepsilon_2)}{2!} \text{Cosh}^{-1} \left(\frac{W+g}{g}\right) \tag{7}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{8}$$

where μ_r and ε_2 is the relative permeability and permittivity of the substrate respectively, μ_0 and ε_1 is the permeability and permittivity of free space respectively, g (mm) is the gap width between adjacent cells, W (mm) is the patch width, h (mm) is the substrate height, f_0 (GHz) is the resonance frequency, C is the capacitance and L is inductance.

This paper presents the jeans as the dielectric material, which has a relative permittivity of 1.7 and thickness of 2.5 mm. By using these values, we may calculate the value of inductance but to calculate the value of capacitance, we must have two more variables, which are the W-width of the patch and g- the gap between two adjacent cells. Therefore, now the dimension is ready to perform the parametric analysis on the unit cell, the literature shows that the desired band of operation can only be obtained by using parametric analysis on the design of the unit cell. In Table 1, parametric analysis of the unit cell is presented.

The parametric analysis will show the effect of various combinations of the equivalent inductive and capacitive circuits. The equivalent circuit of the Unit EBG cell is an inductive and capacitive connected lumped circuit, but when we increase the length of the square in the EBG the inductance of the surface increase. The gap between two conducting squares increases then the equivalent capacitance will increase, so in return, they will change the resonance on which the surface will behave like a high impedance surface. Figure 2(a) depicts the structure of a Unit EBG square cell. The parametric analysis, the result shows the best suitable dimensions to get the band stop function.

Table 1 presents the final selection is mentioned for the 5.5 GHz frequency. In this work, the simulation is being done by using the perfect electric conductor and perfect magnetic conductor boundaries conditions, and energy is fed by using the Floquet port in the Ansys HFSS simulator. The boundary along with the Floquet Port is shown in Figure 2 (b).

In Figure 2, the EBG cell dimensions are as $P_1 = P_2 = 28$ mm, $C_1 = C_2 = 20$ mm, and rest S_1 , S_2 and I_1 and I_2 will remain constant as mentioned in Table 1. The EBG bandwidth starts from 5.281 GHz to 5.8771 GHz, shows that when an incident wave strikes on the EBG surface the mentioned range signals will reflect without change in the phase.

Table 1. *EBG unit cell parameters used for parametric analysis*

S.no	Variable parameters (mm)	Range of Variables	Final Selection
1	S_1	Constant	29 mm
2	S_2	Constant	29 mm
3	P_1	28 mm to 30 mm	28 mm
4	P_2	28 mm to 30 mm	28 mm
5	C_1	20 mm to 21 mm	20 mm
6	C_2	20 mm to 21 mm	20 mm
7	I_1	Constant	18 mm
8	I_2	Constant	18 mm

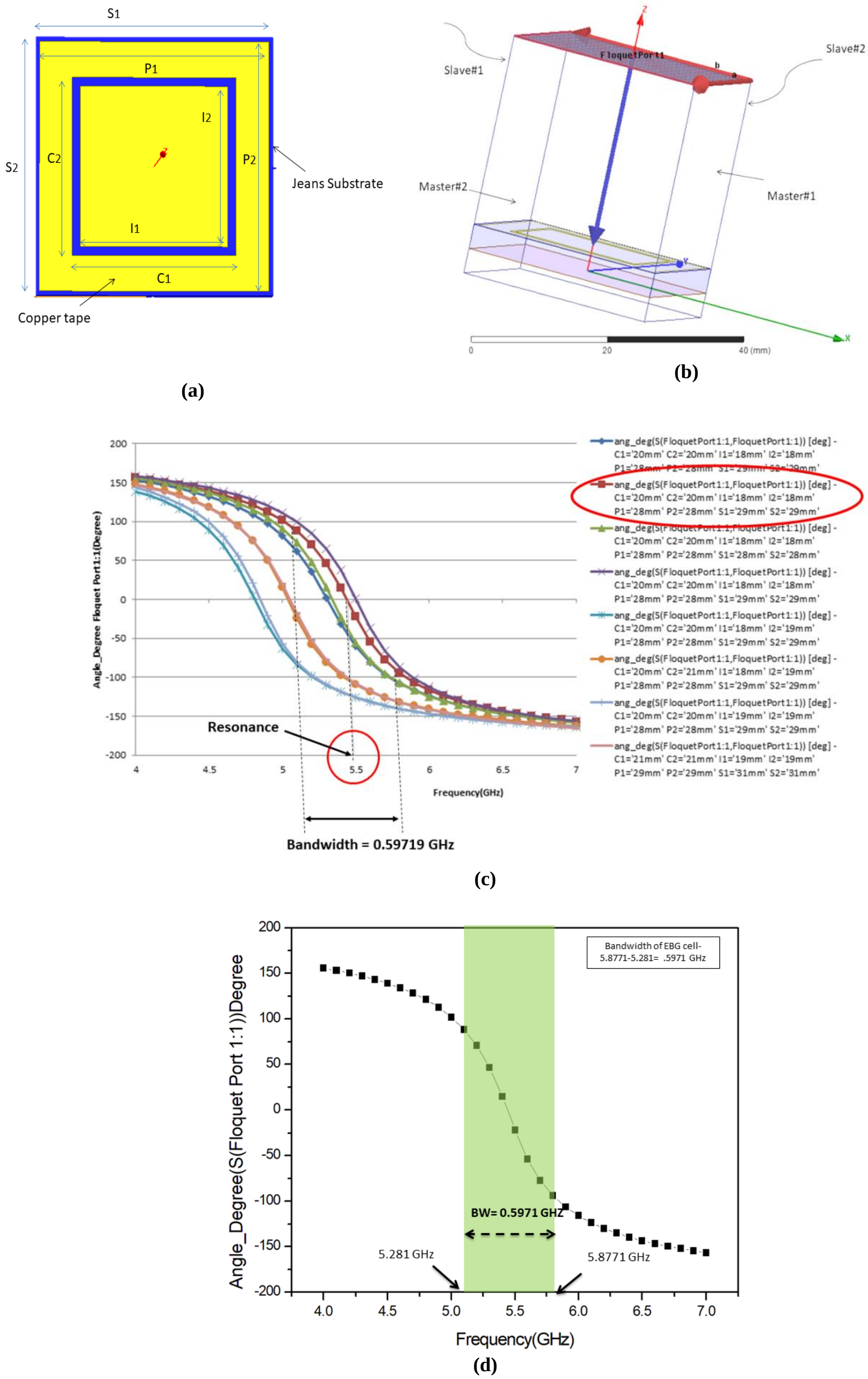
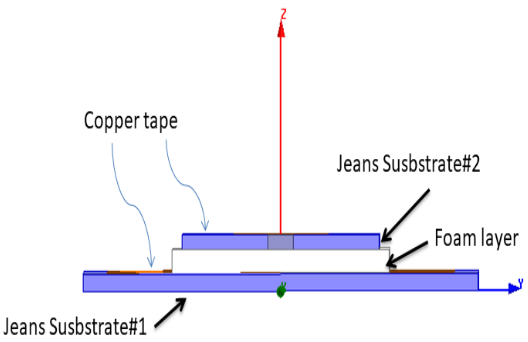


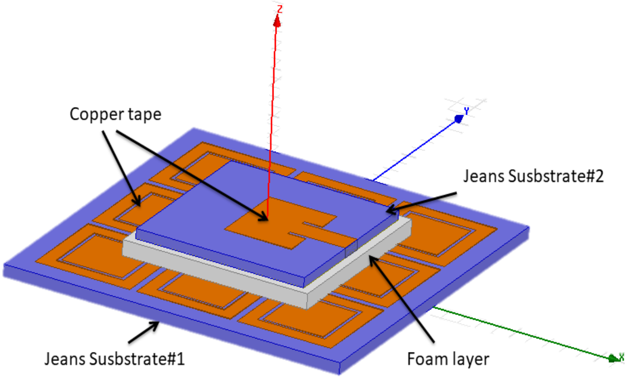
Figure 2. *a) EBG unit Cell on jeans substrate b) The master-slave boundaries and Floquet Port for energy excitation c) Parametric Analysis on EBG Cell d) The desired band to get the Band Gap feature, between + 90^0 to -90^0 represent the EBG bandwidth*

The parametric analysis findings, as well as the needed band 5.5 GHz bandwidth for band stop function, are shown in Figures 2(c). The EBG cell's bandwidth is chosen within a range of $\pm 90^0$ as shown in Figure 2(d). The reflection phase will be in phase with the incident wave, as demonstrated in the bandwidth of the EBG Bandgap in Figure 2(d), the shaded area within $\pm 90^0$ for this range. Because the incident wave will not experience the phase change when it hits the EBG surface, therefore the surface wave will be reduced by a similar amount and the significant energy will be restricted in the +Z direction, which is the direction of propagation.

3.1. Integration of Patch with EBG Surface

The jeans patch antenna has now been integrated with the newly designed EBG array surface as shown in Figure 3. To avoid grounding between the EBG surface and the ground, a 2 mm foam layer is inserted between the EBG and the ground of the patch. The foam layer's dielectric constant is like the air, so it behaves like an air gap between the antenna and EBG surface. This design consists of two substrates. One is the bottom substrate, on which the EBG surface is created, and the other substrate is the top, on which the patch is placed on top, and the bottom works as a ground. Figure 3(a) shows the front view and (b) shows the side view of patch with EBG surface along with foam sheet.





(a) (b)

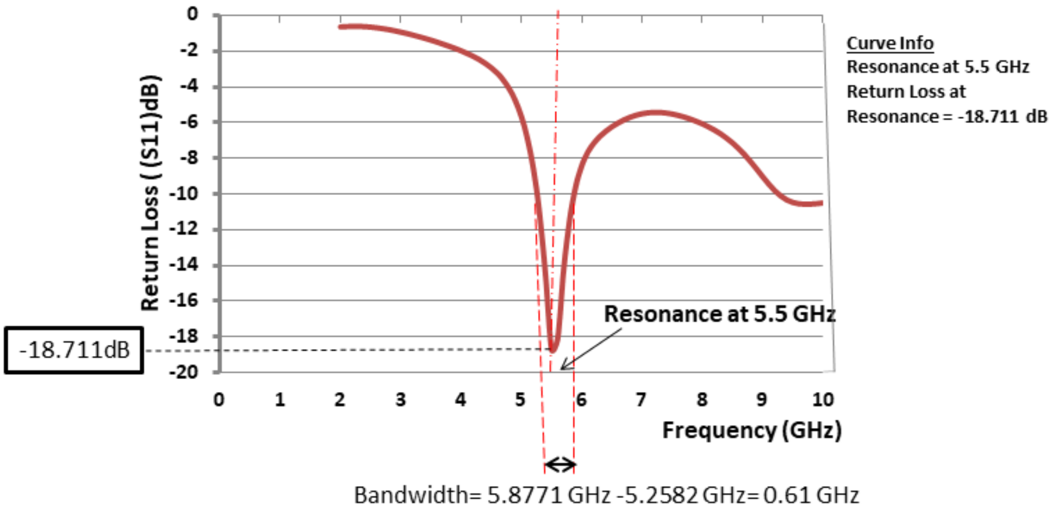
Figure 3. *a) The front view of reference antenna placed on the EBG structure b) Side view of the integrated patch with EBG*

4. RESULTS AND DISCUSSION

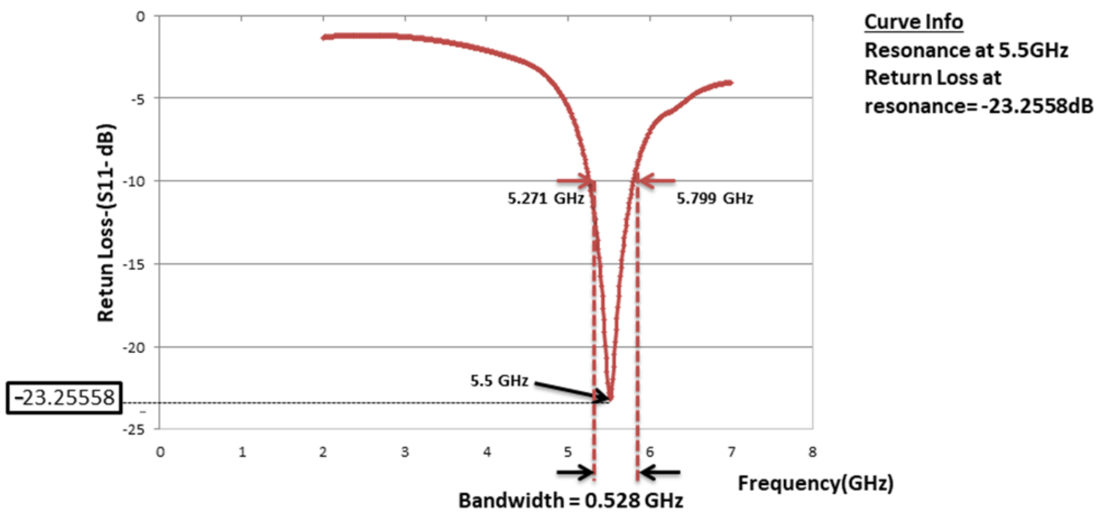
The measurement and analysis of antenna compared with the On-Body and Off-Body measurements. The reference patch antenna first measured without EBG off body performance. The patch antenna mounted on the EBG surface to seek the improved performance parameters.

Return Loss for Off-Body Measurements

The return loss is the performance parameter of the antenna. It shows the amount of power reflected from load due to the impedance mismatching or imperfection in the communication system. In Figure 4(a), the return loss (S11) of patch antenna without EBG shows that the bandwidth is 0.6189 GHz (5.2582 GHz to 5.8771 GHz) on the desired resonance of 5.5 GHz with the value of -18.676 dB. For practical applications below, the value of -10 dB is desired. In Figure 4(b), the return loss of antenna integrated with EBG has been represented as -23.255 dB. The effect of EBG surface is quite clear that the placement of this surface improves the return loss by 20%.



(a)



(b)

Figure 4. *a) Return Loss of jeans patch without EBG Structure b) Return loss of Jeans patch with EBG structure*

Return Loss for On-Body Measurements

Human body model is being designed in Ansys HFSS simulator for the measurement of return loss on the On-Body. The human body parameters such as dielectric constant, penetration depth, conductivity and permittivity vary as frequency changes, so selected the parameters are taken for the 5.5 GHz operating frequency [37]. Table 2 shows the human body model basic parameters for the frequency range of 5.5 GHz.

Table 2. *Human Body tissue properties on 5.5 GHz frequency [37]*

Body Tissue Name	Conductivity [S/m]	Relative permittivity	Loss Tangent	Wavelength [m]	Penetration Depth [m]
Bone	0.26545	4.9906	0.1738	0.024309	0.044844
Fat	0.27374	4.9825	0.17956	0.024322	0.043462
Skin	3.4631	35.363	0.32006	0.009053	0.009229

The basic human tissues model is used to check the performance of EBG based textile patch antenna. Various designing features such as increasing the height of substrate can vary the bandwidth of the antenna. Though the jeans material is already multifold so the substrate width could be increased by increasing the thickness of Foam sheet placed between patch and EBG surface. Therefore, when the EBG based antenna simulated on human body model, the width of the foam sheet is increased to get the better performance. As shown in the Figure 5 the human body model integrated with jeans patch antenna and EBG surface.

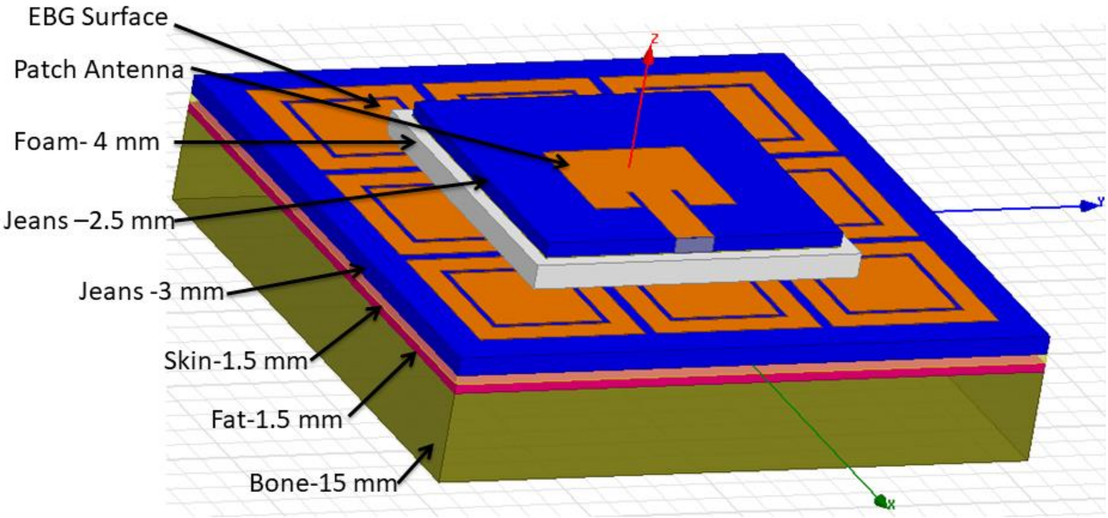


Figure 5. *Jeans based patch antenna with EBG surface placed on human body model*

The return loss of the antenna when placed on On-Body is shown in Figure 6, where the resonance is being shifted 2.6 % to higher frequency from the resonance frequency of 5.5 GHz. The shifting is because of the human body loading. The bandwidth has been improved by 12 % compared to the EBG based patch off body measurements. The placement of 4mm foam sheet is enhancing the bandwidth of the design. The return loss is reduced by 13.9 % when placed on human body. The bandwidth of the EBG based patch antenna when placed on human body tissue model is shown in Figure 6 return loss Vs frequency characteristics.

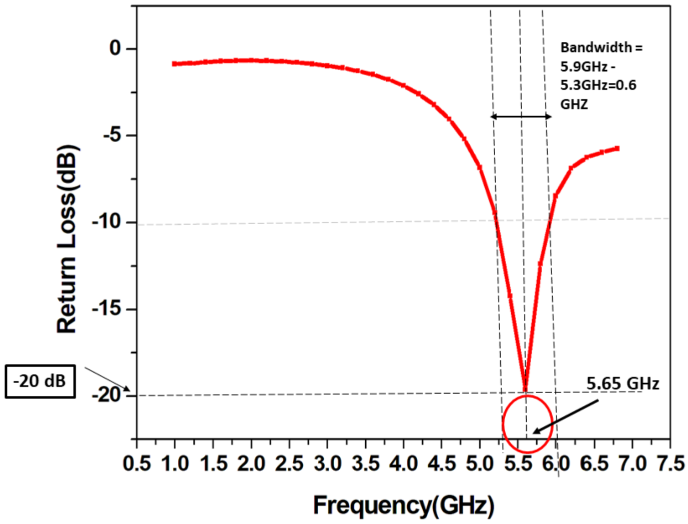
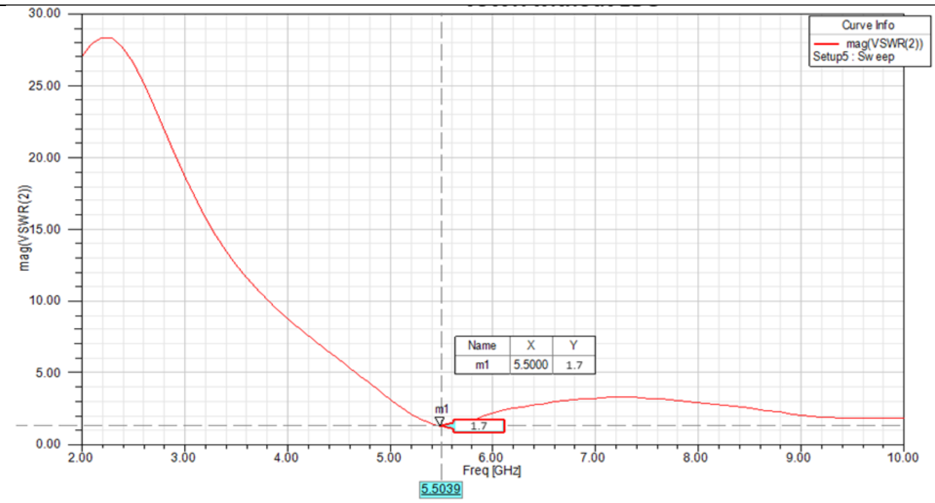


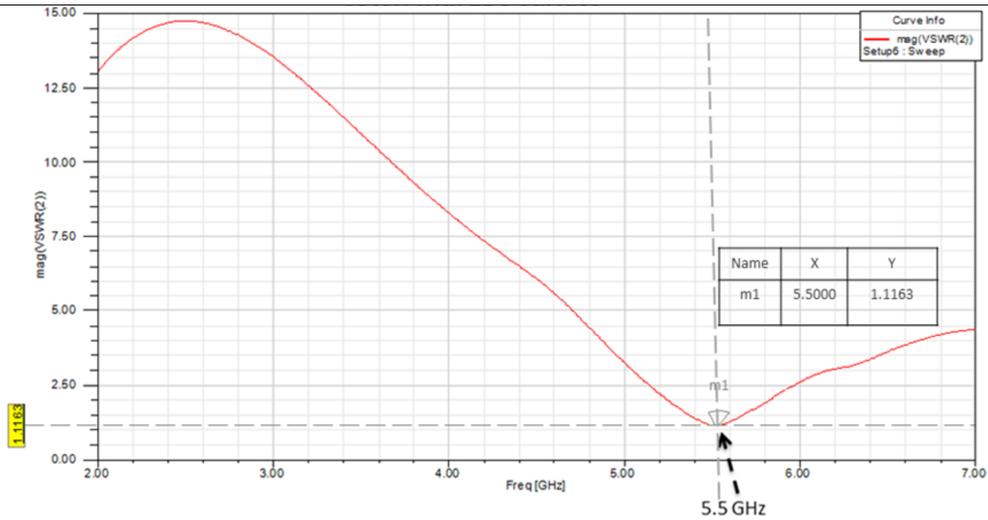
Figure 6. *The return loss of EBG based Jeans antenna placed on human body model*

VSWR

The impedance matching plays a key role in transferring the maximum power from any radiator, the patch antenna impedance matching is represented by the Voltage Standing Wave Ratio (VSWR). The range of VSWR is between 1 to 2, the VSWR of the antenna without EBG shown in Figure 7(a) shows the value is very close to the maximum value, which is 1.7. As much as the VSWR close to minimum value, better will be the impedance matching. In Figure 7(b) shows the VSWR of antenna mounted on EBG surface improved by 34 %. This shows the value of VSWR at 5.5 GHz resonance as 1.116. The EBG surface clearly shows the better impedance matching when it is integrated with patch antenna. Figure 7(c) shows the VSWR value when the antenna placed on human body model, due to the presence of human body tissues the value of VSWR incremented by 13.35 %. Though it is still greater than the value as compared to without EBG. Which clearly shows that the lossy human body tissue's presence changes the VSWR from 1.116 to 1.2880.



(a)



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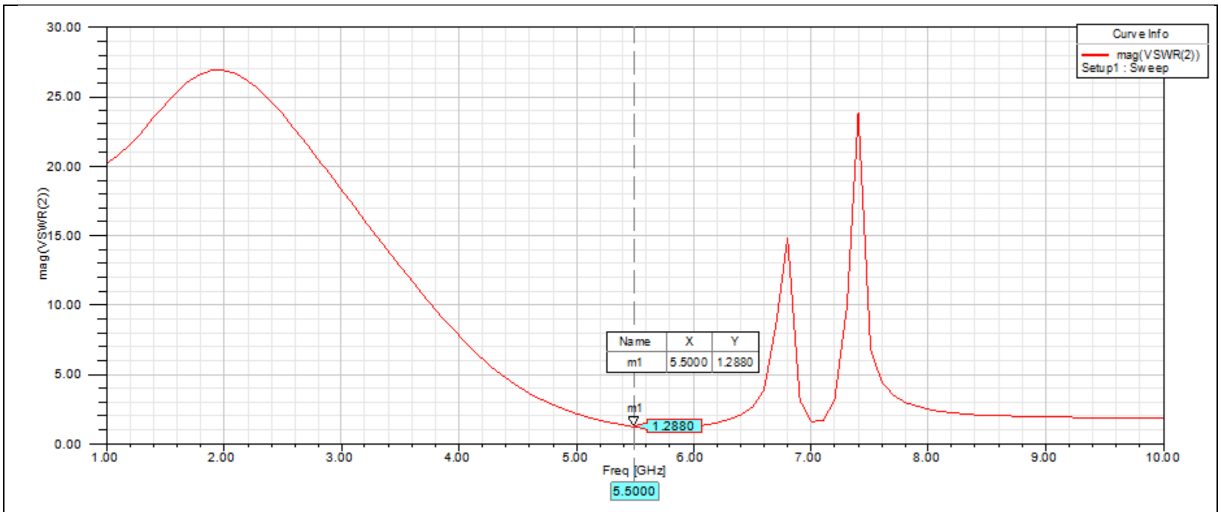
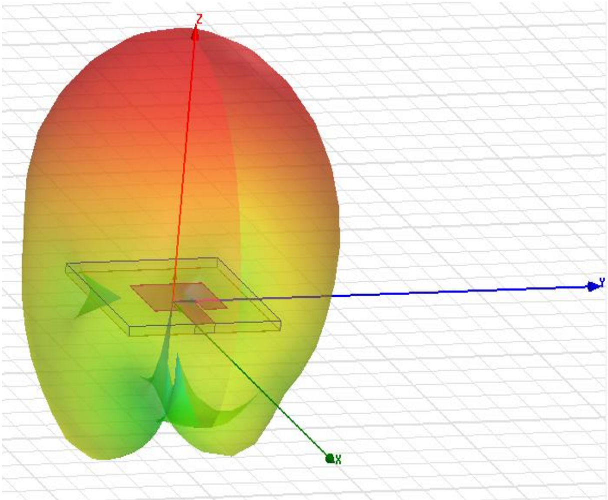


(c)

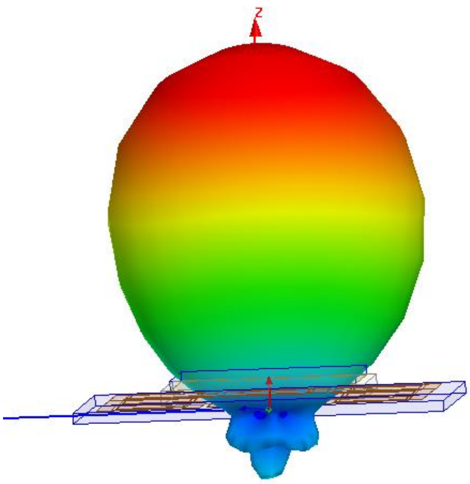
Figure 7. *a) VSWR value for the patch antenna without EBG b) VSWR measurement for the patch antenna integrated with EBG c) VSWR value when antenna placed on human body tissue model*

Radiation Fields

The antenna radiation pattern is the graphical representation of the relative intensity of its energy radiated in free space. The energy radiated in electric and magnetic field strength as a function of the direction of the antenna without EBG and with EBG surface is measured. In Figure 8(a) shows the radiated energy without EBG surface, represents that the radiation in the reverse direction is very strong. The Figure 8(b) part shows the improvements in the radiated energy after integration of antenna with EBG surface.



(a)



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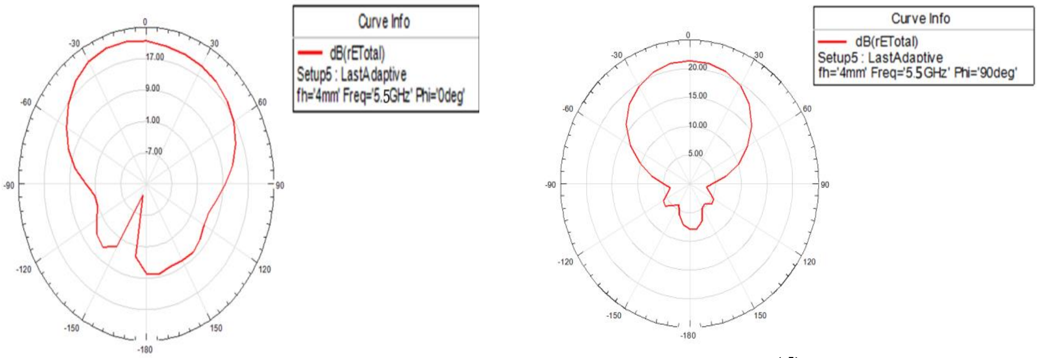


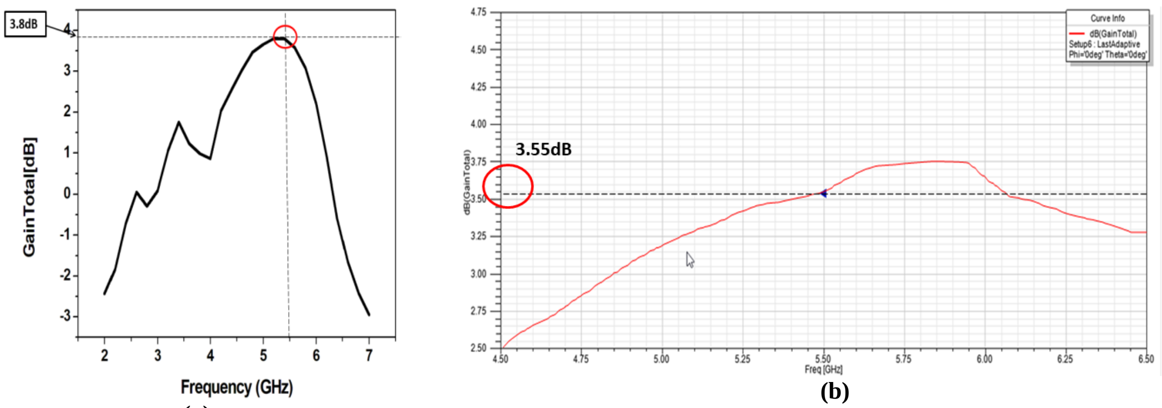
(c) (d)

Figure 8. *a) Simulated 3D radiation pattern of the reference jeans patch antenna without EBG Surface b) Radiation field of the jeans antenna with EBG Surface c) 3-D Polar E-field plot of the patch without EBG structure b)3-D Polar plot of the integrated patch with EBG structure*

The E-Plane and H-plane radiation patterns of the antenna are shown in Figures 8(c) and 8(d). The antenna is oriented to get the maximum radiation in the z-direction. So, the XZ plane will be the E-plane and YZ-plane will give the variations of H-fields.

Gain Vs Frequency

The gain of the patch antenna was improved by various design-related changes such as increasing the thickness of the substrate, using superstate, using aperture coupled instead of any other feed techniques, meandering probe, using a low-loss substrate and increasing the size of the ground planes. Since textile materials are used as a substrate in this study, there are few options for improving the gain. As a result of this restriction, a foam sheet with a width of 4 mm is inserted between the antenna and the EBG construction. The gain for the reference antenna without EBG is depicted in Figure 9(a). At 5.5 GHz resonance, the gain is 3.8 dB. When it was placed on a human body model created with HFSS, as illustrated in Figure 9, the gain was not much affected at the desired resonance, but the maximum gain is now pushed to 5.65 GHz, which is higher than the resonance frequency. The value of the gain at shifted resonance is around 4dB. The resonance was moved to a higher frequency due to the presence of the human body. The presence of human body reduced the gain by 8.5 %.



(a) (b)

Figure 9. *a) Gain Vs Frequency characteristic for the antenna for Off-Body measurements, b) On Body Gain Vs Frequency characteristic for On-Body measurements*

SAR

The Specific Absorption Rate (SAR) is the most important performance parameter when the device must be worn on body or placed in vicinity to human body. When a human body is exposed to a radio Frequency (RF) field the SAR is used to measure the rate at which energy is absorbed per unit mass by the tissues. Its unit is in watts per kilogram. The EBG based jeans textile patch antenna is simulated for the measurement of SAR. The range of SAR is at the limit for practical use, especially for body-worn applications. The SAR of EBG based patch antenna when placed on human body model not much affected after placing on the human body.

5. CONCLUSION

A fully textile antenna with a simple and easy-to-fabricate EBG structure is designed and simulated. In the view of earlier literature, this antenna with EBG is highly directive, so the back radiation on the human body will be competitively very low. Some literature has found good gain for the EBG structure-based rigid antenna on rigid material, but their EBG cell design is complicated. Which is not easily converted to textile, so the purpose of this work is to design the EBG which could be implemented on textile very easily. The highly directive radiation feature has been introduced with the help of this EBG, so along with the main purpose; the EBG also helps to improve the gain and impedance matching even when the On-Body implementation is being done. The EBG implemented successfully with the 34 % better impedance matching and 19% increment in return loss. When the antenna placed on human body the bandwidth has been improved by 12 % but a slight reduction has been found in the gain. Hence, the presented antenna is the simplest to design on textile, along with good impedance matching and almost stable gain in the presence of human body for the 5.5 GHz WiMAX application.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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