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Enhancement of Gain and Bandwidth using EBG Structure for Textile Antenna

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Abstract

In this paper, Rectangular Electromagnetic Band Gap (EBG) Structure and multiple slots on patch are proposed to improve the gain and bandwidth of the Textile antenna. The EBG structure is sandwiched between the patch and the ground plane. A Single band textile antenna has a resonant frequency of 5 GHz used for IEEE802.11a Wireless Body Area Network (WBAN) applications. Four slots are created on the hexagonal patch, so the patch shape appears like WiFi symbol. For this antenna, jeans fabric is used as substrate. The design is simulated using HFSS software.

Keywords: WBAN, Textile antenna, Rectangular EBG, WiFi symbol

INTRODUCTION

The demand is increasing rapidly for wearable electron device from last decade due to availability of portable devices. The wearable electronic devices are used on, off and inside the body. The devices which can communicate with each other around the body is known as Wireless Body Centric Communication. Depending on the range of communication, Wireless Body Area Networks (WBAN) and Wireless Personal Area Networks (WPAN) are possible. The body worn devices are used for monitoring the health conditions of patients, battle field persons and energy expenditure of sports persons [1].

The main criteria for wireless components for body communication is to support high data rate, light weight, small size and low power consumption. The conventional microstrip antenna has to satisfy the above conditions but it is not flexible and comfortable to wear on the user body. This problem can be avoided by using textile materials. The fabrics are available in either conductive or nonconductive form. Conductive fabrics like Zelt, Flectron are used for ground, patch and nonconductive fabrics like cotton, polyester, felt are used for substrate [2]-[3].

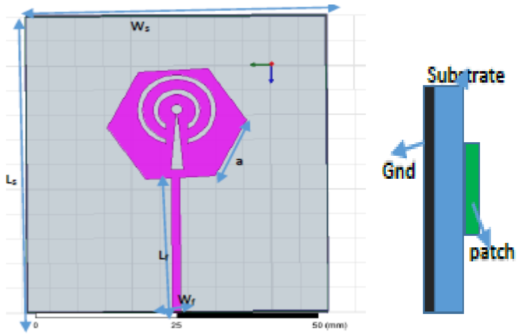
The wider bandwidth supports high speed data transfer but the textile antennas have low gain and narrow bandwidth. Bandwidth can be increased by different methods such as,

$$\text{Impedance Bandwidth} = \frac{VSWR-1}{Q_T\sqrt{VSWR}} \quad (1)$$

Where, VSWR is Voltage Standing Wave Ratio, Q_T is Total Quality factor. The impedance bandwidth is inversely proportional to the quality factor. When substrate thickness is increased, the energy stored decreases. Bandwidth is directly correlated to the thickness of the substrate provided if the thickness is increased the antenna size will also increase [4]. The authors proposed multi layers with defective substrates to improve the gain and bandwidth of the antenna. Here, silicon with ϵ_r=11.9 and glass with ϵ_r=4.6 are used as substrates, it's resonant at 6.64GHz. The multilayers with patch increases the bandwidth and partial substrate improves the gain [5]. The authors proposed superstrate technique in which the top of the patch antenna is covered with Mu near zero meta surface and it is resonant at 2.45GHz. The structure of meta surface is dual closed loop patches on FR4 substrate. The periodicity of unit cell is 20mm [6]. The micro strip antenna consists of 11 layers, three stacked parasitic strips and LTCC is used as a substrate. It is fed as aperture coupled. Using Stacked Parasitic Strips (SPS), it guides the radiation towards broadside direction so the directive is enhanced. The resonate frequency of the antenna is 3.5GHz. The multiple modes are excited due to SPS, so bandwidth is increased [7].Using mushroom type EBG structure, the gain and bandwidth is improved and it is resonant at 10GHz. The substrate material is neltec with ϵ_r=2.45[8]. Dual band microstrip antenna is designed using mushroom type EBG structure and resonant at 4.8 GHz, 7.6GHz with gain of 4.1dBi. Multiple slots created on patch and FR4 material is used for the substrate [9]. The impedance matching network also augments the bandwidth and leads to reduction in the return loss but desirable configuration is not obtained [10].In [11], 15x7 cells are used as Metasurface for enhancement of bandwidth and gain of Dipole antenna, resonant from 4.15 GHz to 5.85 GHz . It is implemented on FR4 substrate. In [12], the inset feed Microstrip antenna is combined with double annular slot resonator (DASR) cells (5x5). The cells are used as superstrate for improvement of gain and bandwidth. It is fabricated on Neltec substrate material.

The paper is arranged as: the analysis of textile antenna and the proposed method for rectangular EBG structure is given in section II, the results and discussion are given in section III, and finally, the Conclusions are given in section IV. The application of the proposed textile antenna is IEEE802.11a WBAN.

ANTENNA DESIGN



(a) (b)

Figure 1(a) Schematic of Textile antenna **(b).** Side View

Initially, the proposed Textile Antenna contains a substrate in between the patch and Ground surface and it is shown in figure1 (a).Figure 1(b) shows the side view of the textile antenna. The Copper is used for ground, feed line and patch. The Jeans Fabric is used as substrate that has dielectric constant of 1.67 with Loss tangent of 0.025 [13].The substrate thickness is 2.4mm with length L_s = 60 mm and width W_s =54 mm. The size of full ground is 60 mm x 54 mm. The patch shape is hexagonal and four slots are created on the patch. The length of each arm of hexagonal patch is a=12.5 mm. The width of two arc slots is 1mm and the radius is 1 mm of circular slot. The length of right, left arms are 11.4 mm each and bottom side is 2.3 mm for the triangle slot. The Dimensions of the Microstrip line feed is W_f=1.5 mm x L_f =28 mm.

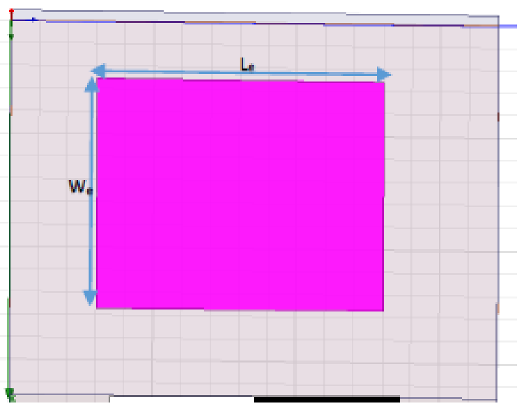
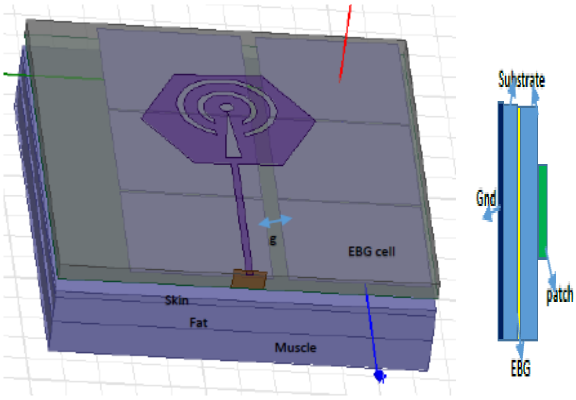


Figure 2. Rectangular EBG cell

The proposed Rectangular shape EBG cell is shown in figure 2. The unit cell length is L_e=20.3mm, width is W_e=19.6 mm and it is implemented on jeans substrate with thickness of 1.6mm. The gap between the two successive cells is 2.2mm along lengthwise and 0.4mm along the width. The EBG structure has periodicity of 22.5mm. The array of rectangular shape EBG structure is 3x3.



(a) (b)

Figure 3 (a) Textile Antenna with EBG. **(b)** Side View

The Rectangular EBG array is integrated with the textile antenna on phantom model of human body as shown in figure 3(a). Figure 3(b) shows the side view of the proposed Textile antenna. The EBG array is positioned at 1.6 mm, the patch is placed at 2.4 mm from the ground plane respectively. The gap is filled with jeans fabric and it acts as a substrate. Here, the dimensions of the patch, ground and substrate are not changed. The distance between the body and the ground plane of the antenna is 2 mm.The phantom Model of Human body is created for simulation [13]. Value of body tissues are shown in Table-I

Table I. Body Tissues at 5GHz

Tissues	Thickness (mm)	Conductivity [S/m]	Relative permittivity	Loss tangent
Skin(wet)	2	3.5744	39.611	0.32441
Fat	6	0.24222	5.0291	0.17315
Muscle	10	4.0448	49.54	0.29353

RESULTS AND DISCUSSIONS

All the results are analyzed using Ansoft-HFSS software. Using parametric analysis reflection phase is chosen. Variation of width of the unit cell has low effect on the phase curve but variation of length effects more on the reflection phase that is shown in figure 4.

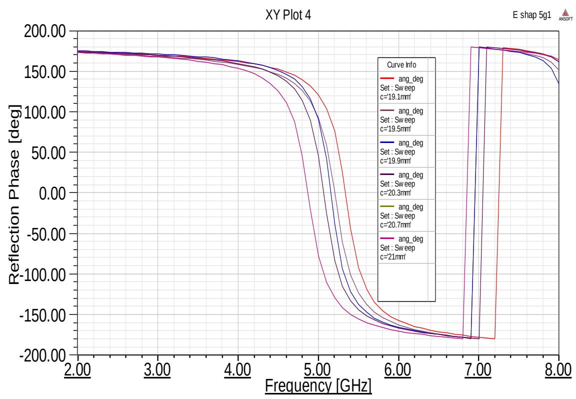


Figure 4. Parametric analysis of length of EBG cell.

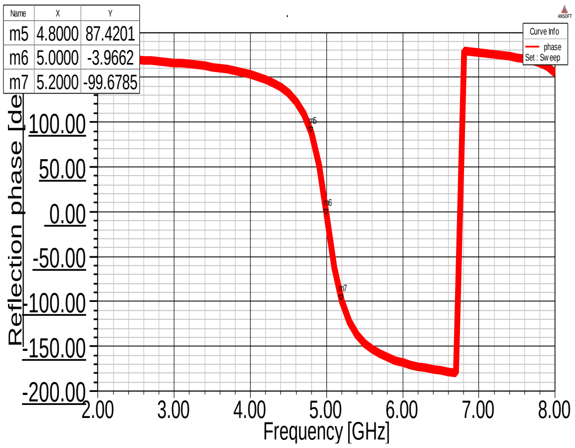


Figure 5. Reflection phase of rectangular EBG cell

The curve between frequency and reflection phase of the proposed rectangular-shape EBG cell is shown in figure 5. The reflection phase changes from 4.8 GHz (90^0) to 5.2 GHz (-90^0) and Reflection phase is 0° at nearly 5 GHz. The EBG structure provides better radiation characteristics within a particular frequency band (4.8-5.2 GHz) due to the constructive image current. It is a unique characteristic of the EBG structure.

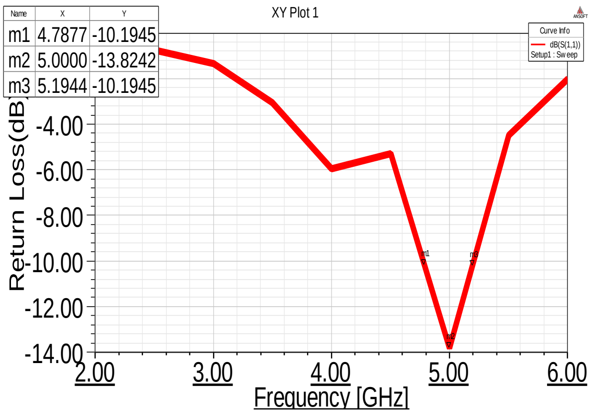


Figure 6. Return Loss of Textile Antenna without EBG

The graph of frequency versus return loss of the Textile antenna without EBG structure and with human body is given in figure 6. The textile antenna is resonant at 5GHz with return Loss of -13.82dB. The Impedance bandwidth is the difference of the upper cutoff frequency to the lower cutoff frequency and uses -10dB as the reference line. It has an impedance bandwidth of 410 MHz from 4.78 GHz to 5.19 GHz.

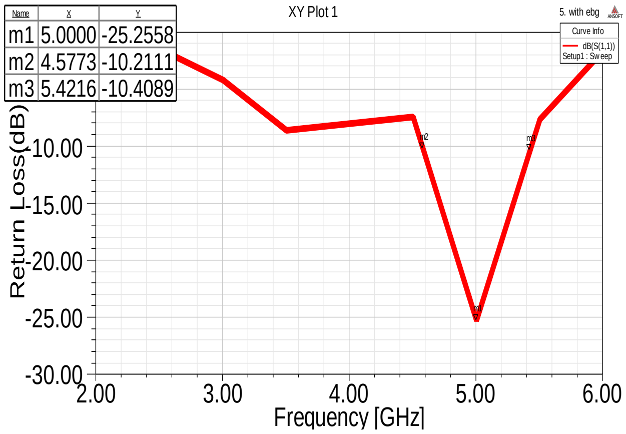


Figure 7. Return Loss of Proposed Antenna with EBG structure

The figure 7 shows the Return Loss of the proposed Textile antenna with rectangular shape EBG structure on phantom model of human body. It has return loss of -25.25 dB at 5 GHz and impedance bandwidth of 850 MHz from 4.57 GHz to 5.42 GHz. The impedance bandwidth is increased due to Rectangular EBG structure.

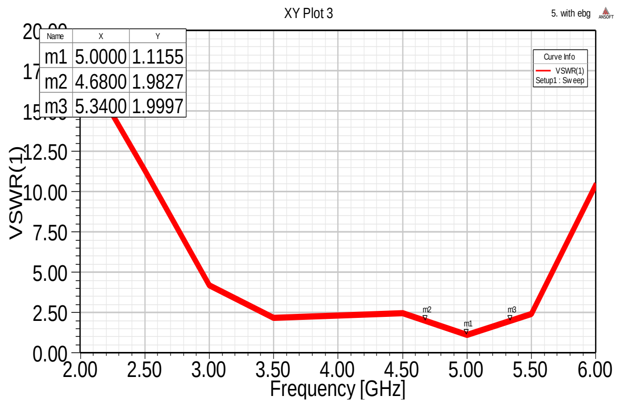


Figure 8. VSWR of Textile Antenna with rectangular EBG

The graph of frequency versus VSWR value of the proposed Textile antenna with rectangular EBG array on phantom model is shown in figure 8. The VSWR value is less than 2 from 4.68 GHz to 5.34 GHz .It has low VSWR value of 1.21 at 5 GHz.

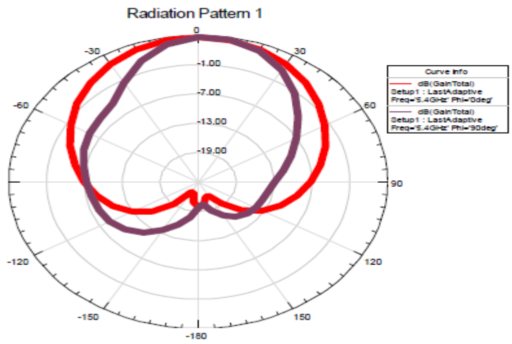


Figure 9. Radiation Pattern of Textile Antenna with rectangular EBG array.

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The radiation pattern of Textile antenna with EBG structure on phantom model is shown in figure 9. The back lobe radiation is decreased due to EBG structure.

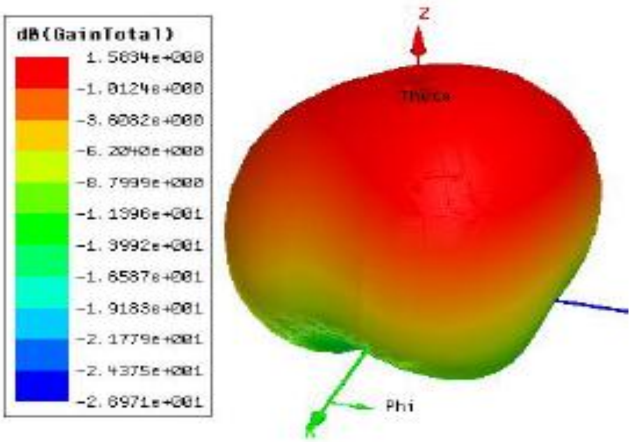

Figure 10. Gain of conventional Textile antenna on phantom model.

The figure 10 shows the Gain of the Textile antenna without EBG structure and with phantom model. The gain of the proposed antenna is 1.58 dB.

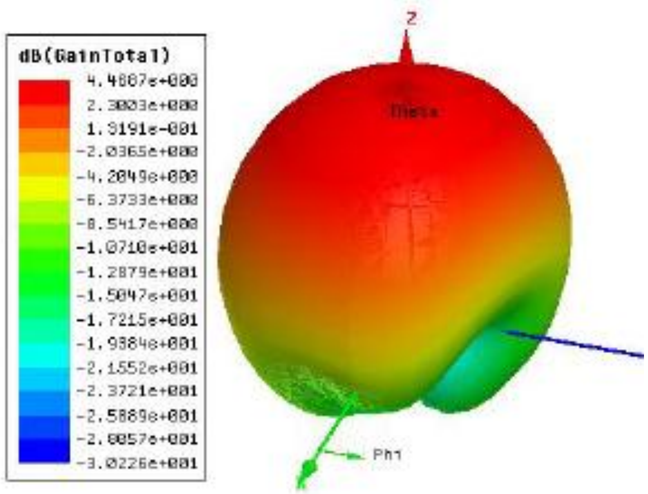

Figure 11. Gain of the Proposed Textile antenna with EBG structure.

The gain of the proposed textile antenna with Rectangular EBG array on phantom model is shown in figure 11. The gain of the proposed antenna is 4.48 dB. The waves reflected between the ground and superstrate of EBG array, then aperture size is enhanced. The gain and bandwidth is increased due to EBG structure. EBG array reduces the back lobe radiation and enhances the gain.

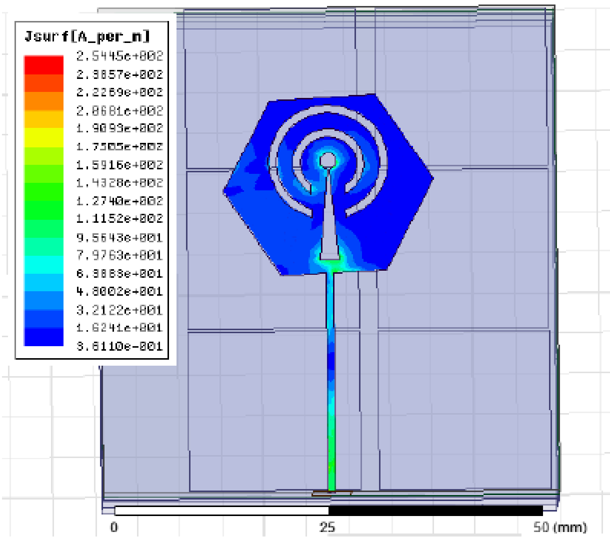

Figure 12. The surface current distribution of textile antenna

The surface current distribution of the proposed Textile antenna with EBG array on phantom model of body is shown in figure 12. The maximum current is distributed across the bottom and middle of the patch.

Table II. Comparison of Radiation characteristics of the Antennas

Parameters \ Ref	Ref[15]	Ref[16]	Proposed Antenna
Frequency(GHz)	2.41	2.41	5
Return Loss(dB)	-36.5	-17.75	-25.25
Gain(dB)	0.95	6.61	4.48
Bandwidth(MHz)	250	101	850
Shape of EBG	Split Ring	Spiral	Rectangular

Table II shows the comparison of radiation parameters of the different antennas with EBG structure. Here, Ref [14] and proposed antenna characteristics are calculated using phantom model and Ref [15] results are without phantom model of human body.

CONCLUSION

In this paper, the textile antenna is combined with rectangular EBG structure on phantom model which is resonant at 5 GHz with Return loss of -25.25 dB. The impedance bandwidth is increased by 51.7% due to the rectangular EBG structure. The gain of the antenna is also increased from 1.58dB (without EBG) to 4.58dB (with EBG). Finally gain and bandwidth of the proposed textile antenna is increased due to the rectangular EBG structure.

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