Denim EBG Based On Ultra High Frequency Wearable Antenna

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***Abstract*—A curtailed wearable textile antenna is designed through HFSS simulator software. The inverted E shaped antenna is designed for UHF applications at 2.9 GHz. In this antenna uses appropriate rectangular slot with microstrip line, that slot appearing on the radiating patch. It increases the current radiating path length and highly diminishes the resonant frequency,50 ohm microstrip line is fed to the textile antenna. The structure is uncomplicated and easily manufactured by using denim material. The size of the antenna is 30 x 20 x 0.7 mm3. The perspective of designers is more important in economic aspects in a fabrication. The designed inverted E antenna's frequency is 2.9 GHz, the radiation part of patch up to 1.91 to 5.59dBi.The radiation pattern of the antenna in H plane having omnidirectional radiation pattern and bidirectional in E plane.**

***Keywords*— Textile, UHF, Wearable antenna, Denim, Resonant frequency, E patch**

I. Introduction

In present days increasing the attentiveness have been placed on the area of wearable computing systems, due to the potential applications in several areas like health monitoring for elderly/ children, observing human gesture, physical training, capture, and emergency rescue systems. An antenna plays an imperative role in a wearable device. It is close proximity to the human body with its various curvatures and complexities [1]. It is subjected to structural bending, mismatch, and losses caused by the body. The problem is tackled by the sustainability of the antenna, the wearable antenna must be low profile, robust and lightweight.A Radiation from the wearable antenna should have least Specific Absorption Rate. Miniaturization of wearable antennas is a firmly established topic, with recent trends and developments [2]. It is arduous to miniaturize a wearable antenna while maintaining a low profile, simple design, easy integration capability.The following techniques have been proposed to lessen the physical size of a patch, including the use of high dielectric substrates [3], magneto-dielectric substrates [4], lengthening the current path of the radiator [5], [6],capacitive loading [7], [8], shorting pins/walls [9], embedding tails along the edge [10], fractal PIFA [10], [12] and Quarter- Mode designs [13].Due to the motion of the human body, it is difficult to achieve the proper polarization alignment of the transceiver nodes for better power reception [14]. The manufactured antennas are not linearly polarized and mostly non-flexible because of the large thick substrate it makes them disturbed to be in real time wearable applications.A body area network (BAN) system consists of various nodes attached to different body parts. These nodes are reliable for communicating with each other and transmitters and transmitting the data to any remote server [14]. That node is subdivided into a sensor, an actuator and a Personal Digital Assistant (PDA). The memory unit is under the sensor, it is the most important part for the purpose of data storage and an antenna for gathering the transmitting and receiving data.A biosensor placed on the body of the person which transmit measured signals via remote wireless monitor for acquiring the observed human physiological signals. The absorbing platform was implemented by exploiting technologies like ZigBee and GSM.BAN antennas must satisfy the following things[15], there are compactness, light weight, flexibility and retain their shape, Radiation should away from the human body, Stable characteristics in the human body vicinity.In sensing textile platform sensors are knitted on the clothes.The printed antenna provides a guaranteeing better sensitivity and reduces the burden to the patient.To overcome a problem in the patch can be solved by the following techniques such as increasing the substrate thickness by adding multiple layers, and introducing parasitic elements or modifying the patch's shape itself.Such as includes designing an E-shaped patch and slotted U.

References	Dimension in mm3	Permittivity	Frequency (GHz)
[2]	30 x 20 x 0.7	1.7	2.4
[15]	56 x 65.5 x 1	4.4	5.09
[21]	44 x 34 x 6	1.26	2.45/5.2
[23]	59.6 x 59.6 x 3.7	1.5	2.4
[24]	54 x 36 x 2	3.5	2.4
[25]	63 x 24.8 x 7.3	2.2	2.4
[26]	90 x 70 x 1.57	1.6	2.45
Proposed design	30 x 20 x 1.4	1.7	2.9

Table 1. Performance comparison of proposed antenna with antennas from previous studies with respect to size, permittivity and frequency

II ANTENNA DESIGN AND APPROACH

The antenna design was based originally on conventional Microstrip Patch Antenna (MPA) design techniques [2] and optimized to operate at 2.9GHz using HFSS.Consider the reference textile antenna [2] of Fig. 1, with a width and length of 30 mm and 60 mm, respectively. The ground plane is 8 mm long. Denim material is used as a Shieldit^{TM} conducting material in a textile antenna, it is a combination of cotton and polyester. The thickness of the denim substrate is 0.7 mm with the low dielectric constant of 1.7, and the patch is fed by a 50-ohm microstrip line.

Antenna miniaturization is accomplished by adding slot(or notch) in the patch of the antenna[17]. The cutting slots on the patch increase the effective current path length and the surface will reroute the current distribution. It reduces the resonant frequency and widened its bandwidth.

The substrate is used to increase the dielectric constant and resonant frequency, always the patch is above the substrate. Figure 1. Shows the basic antenna structure Microstrip Feeding line is directly given to the patch, the substrate is sandwich between ground and the patch,The following parameters are important to design a rectangular patch microstrip antenna, there are calculating the width and length of the patch, feed location position[18].

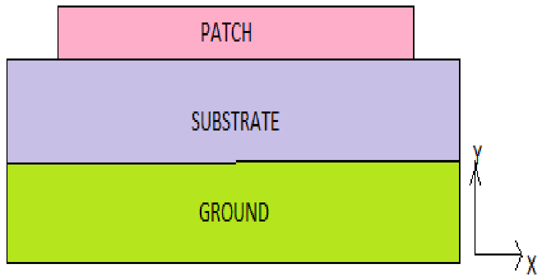

Figure 1.The basic antenna structure

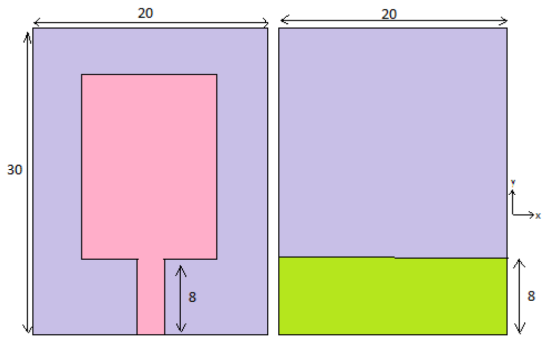

Figure 2.Reference antenna’s front view and back view

A . *Feeding Techniques*

A feeding is used to excite the antenna to radiate by direct contact with a patch or indirect method. The most popular methods are microstrip line feed, coaxial probe, aperture coupling, and proximity coupling. One of the easiest feeding methods is a microstrip line feed[20]. This feeding technique is easier to fabricate as it a just conducting strip directly connecting to the patch and it is considered an extension of the patch. The main advantage of this method is easy to control the inset position.

B. *Material*

In consumer electronics, flexible is becoming an important thing due to lightweight, low cost of manufacturing, ease of fabrication. The availability of flexible substrate like paper, textiles, and plastics[19]. It meets the requirement of different platforms using different antenna technologies, for example, robot devices or on human clothes, lightweight and low power antenna system, the coverage of the antenna range from short(10 m) to medium range(5km-10km).

The substrate material cotton has dielectric constant of 1.7 which is similar to the dielectric constant of most commonly used substrate denim material's dielectric constant, the loss tangent of the cotton material is 0.0314, and the substrate material polyester has dielectric constant of 1.7 which is similar to the dielectric constant of most commonly used substrate denim material's dielectric constant, the loss tangent of the cotton material is 0.044.

C. *Design Methodology*

The solid cube is created in the worksheet and assign the material as denim for textile antenna applications. The values of the substrate are calculated[18] and shown in table 2. The ground is drawn below the substrate from the calculated table 2 parameters. A sheet is used to create the patch, it is drawn above the substrate. In this method, microstrip direct feedline is assigned to the patch. For the port creation, the coordinates of the worksheet are changed xy to xz. The port is drawn in the z plane. The port is assigned as a lumped port. The substrate is a sandwiched between a patch and the ground, a perfect E is assigned both the patch and the ground. A radiation box is installed over the antenna design, the solid is considered as an air. The antenna is radiating in the air medium.

The analysis setup is made up for 2.45 GHz and the fast sweep is used to determine the antenna's start and stop frequencies. The design settings,3D model, boundaries and excitations, mesh operations, analysis setup,optimetrics, and radiations are validated. The overall analysis calculated the following parameters return loss, VSWR(Voltage Standing Wave Ratio), gain, directivity, and the antenna radiation.

PARAMETERS	**VALUES**		
	X	**Y**	**Z**
Substrate	20	30	0.7
Ground	20	8	-
Patch	16	20.45	-
Microstrip Feed line	2.3	8	-
Feed	2.3	-	-1.4

Table 2. Reference antenna parameters and values

III ANTENNA PERFORMANCE

The following figures show the different slot shapes, there is figure 3. Upper slot antenna, figure 4.E shaped antenna, figure 5.S shaped antenna and figure 6. Inverted E antenna.

A. *Basic Rectangular Patch*

The structure of the antenna is shown in figure 2.Denim material is used as a substrate, the thickness of the denim is 0.7 for the basic structure. It radiates at the frequency of 4.8 GHz with return loss (S11< -6.9 dB).Table 2. Shows the parameters values of a rectangular patch.

B. *Rectangular Patch With Upper Slot*

The plate is steered as an antenna by a driving frequency, the slot radiates electromagnetic (EM) waves in a way similar to a dipole antenna. The main advantage of this antenna is size reduction, simplicity, and convenient adaptation to mass production using as a waveguide.

The slot increases the current path length and reduces the resonant frequency.Figure 3. Upper Slot patch radiates at 2.8 GHz with return loss(S11<-9.7 dB).The following table shows the calculated values for the upper slot patch.

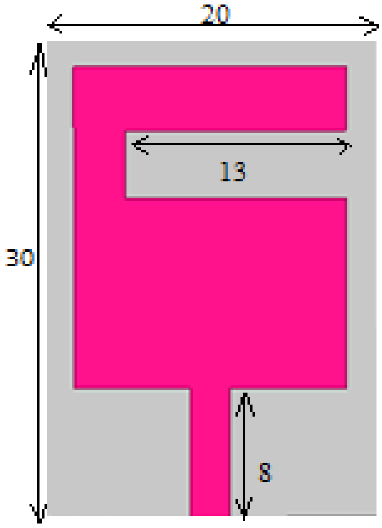

Figure 3.Patch with Upper Slot

PARAMETERS	VALUES		
	X	Y	Z
Substrate	20	30	0.7
Ground	20	16.5	-
Patch	16	20.45	-
Upper Cut	13	4.65	-
Position	-5	4.65	0.7
Microstrip Feedline	2.3	8	-
Feed	2.3	-	-1.4

Table 3.Upper Slotted antenna parameters and values

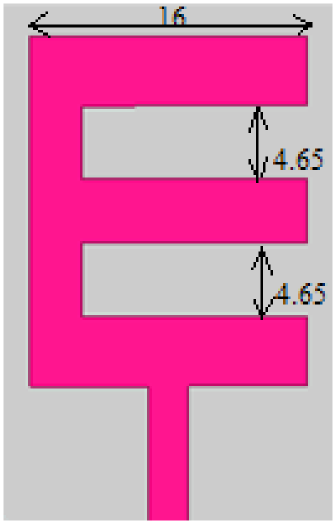

Figure 4.E Shaped Antenna

PARAMETERS	VALUES		
	X	Y	Z
Substrate	20	30	0.7
Ground	20	16.5	-
Patch	16	20.45	-
Upper Cut	13	4.65	-
Position	-5	4.65	0.7
Lower Cut	13	4.65	-
Position	-8	4.65	0.7
Microstrip Feedline	2.3	8	-
Feed	2.3	-	-1.4

Table 4.E Shaped Antenna parameters and values

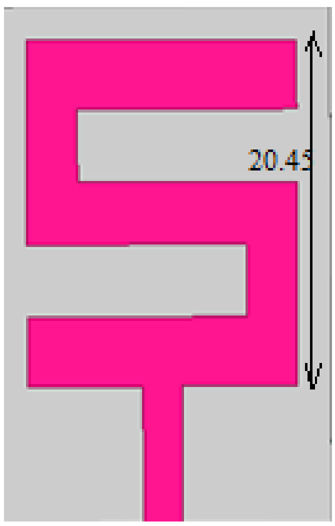

Figure 5.S Shaped Antenna

PARAMETERS	VALUES		
	X	Y	Z
Substrate	20	30	0.7
Ground	20	16.5	-
Patch	16	20.45	-
Upper Cut	13	4.65	-
Position	-5	4.65	0.7
Lower Cut	13	4.65	-
Position	-8	-4.65	0.7
Microstrip Feedline	2.3	8	-
Feed	2.3	-	-1.4

Table 5. S Shaped Antenna parameters and values

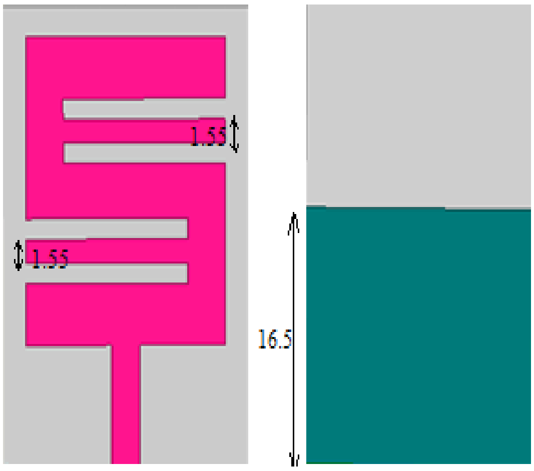

Figure 6.Inverted E Antenna's Front view and Back view

PARAMETERS	VALUES		
	X	Y	Z
Substrate 1	20	30	0.7
Position	-10	-15	0
Substrate 2	20	30	0.7
Position	-10	-15	0.7
Ground	20	16.5	-
Patch	16	20.45	-
Upper Cut	13	4.65	-
Lower Cut	13	4.65	-
Upper Cut 1	13	1.55	-
Lower Cut 1	13	1.55	-
Microstrip Feedline	2.3	8	-
Feed	2.3	-	-1.4

Table 6. Inverted E Antenna parameters and values

C.*E Shaped and S Shaped Antenna*

E shaped antenna is created by inserting slots on the patch. The following table 4 shows the values of the slot and figure 4 explains how the slot is created. It radiating at the frequency of 4.2 GHz with return loss(S11<-8.2 dB).The main purpose of inserting slot is reducing the patch size and to provide the large path for radiating. Figure 5 explains the S-shaped slot creation, table 5 shows the S-shaped antenna parameters and calculated values. It radiating at the frequency of 1.6 GHz with return loss(S11<-9.26 dB).

IV RESULT ANALYSIS

The inverted E shaped antenna radiating at 2.9 GHz with return loss(S11<-24.61 dB) figure 8.This Ultra High Frequency is achieved by inserting slots on the patch. Figure 6 shows the front and back view of the inverted E shaped antenna, table 6 shows the parameters and calculated values of the inverted E antenna. Double substrate technique is implemented in this antenna design. It increases the bandwidth and gain and also improves the return loss of the antenna.The radiation is ranging from 1.91 to 5.59dBi shows in figure 9.Antenna 3D radiation Pattern.

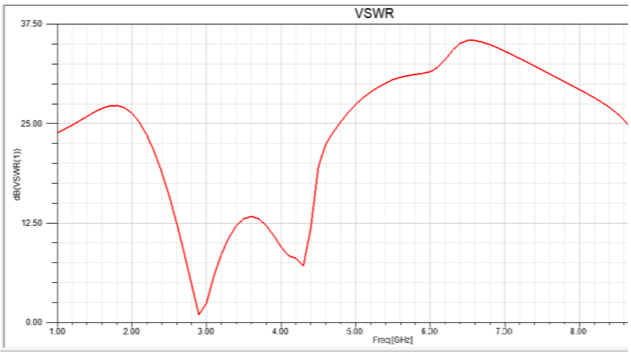

Figure 7. VSWR

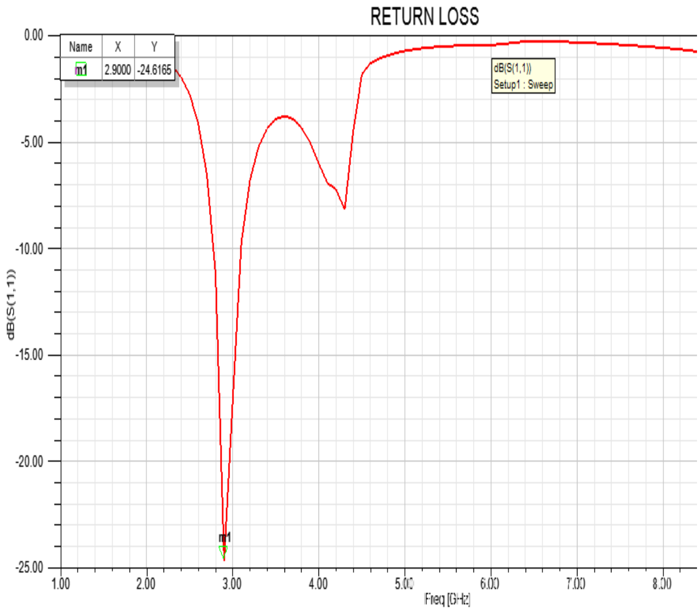

Figure 8. Return loss for inverted E shaped antenna

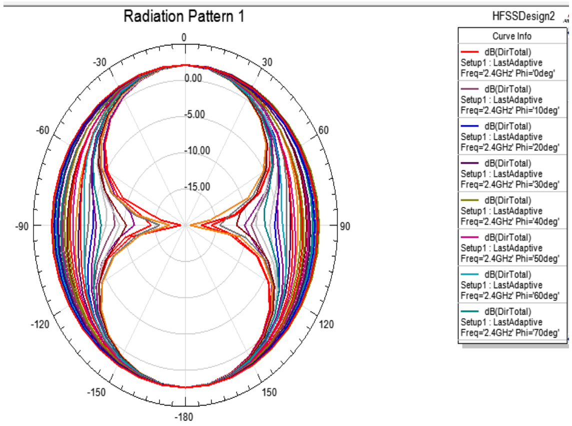

Figure 9.Radiation Pattern

V. EBG DESIGN

In order to achieve a compact EBG structure, a T-shaped connected as strip line pattern is chosen. As mentioned in [1], in order to obtain a compact size, more inductance needs to be introduced into the design. Hence, a strip line pattern is proposed to represent the inductance. An optimum of 1 × 1 EBG array is chosen and placed on a denim material with overall dimensions of 40 x 40 x 0.7 mm$^{3.}$ The EBG acts as an artificial magnetic conductor (AMC) when its reflection phase varying from -180° to +180° and band gap when it is capable to suppress the surface wave at certain operational frequencies.

A. *EBG Structure and Result analysis*

The antenna is placed above the EBG structure as can be viewed in Fig. 10. EBG in order to reduce the mismatch and any electrical contacts to prevent from short circuit.The EBG is flexible to the attached material and surrounding,it will ensure the minimum changes to the structure of the antenna.

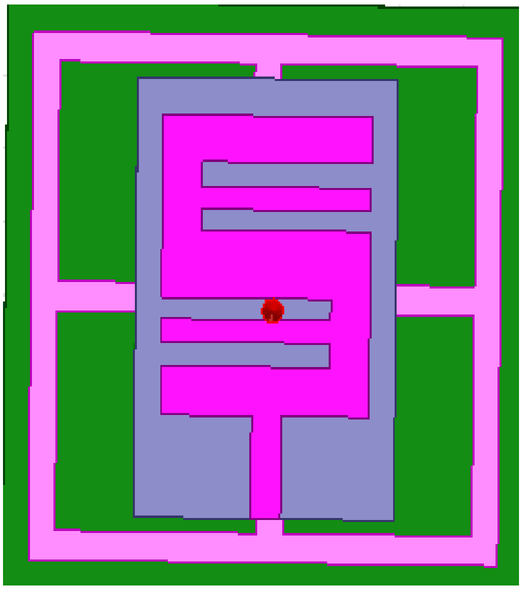

Figure 10. EBG Stucture with inverted E antenna

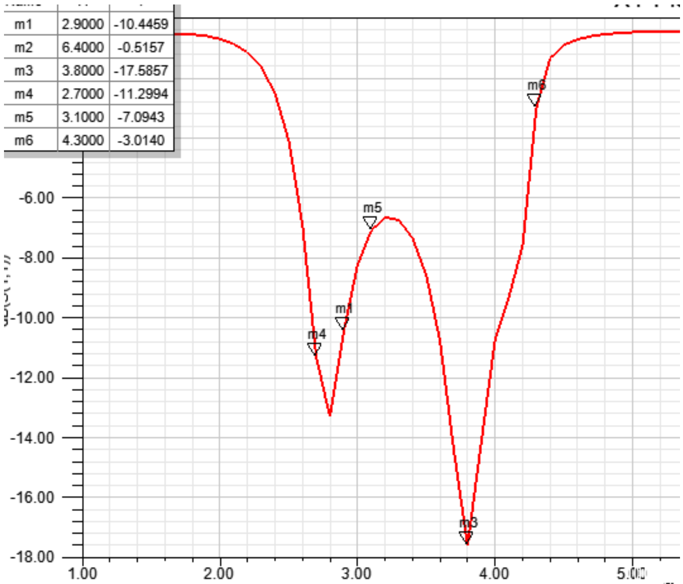

Figure 11. Retrun loss for EBG based inverted E structure

V.CONCLUSION

A low profile and lightweight curtailed antenna for UHF applications at 2.9 GHz have been presented, denim material is used to construct the antenna. The size reduction is reached by loading proper rectangular slots and inserting strip lines, the proposed antenna is 75% miniaturized compared to the reference antenna. Overall, the proposed antenna represents a suitable candidate for UHF applications due to its low fabrication cost, small size, and acceptable radiation and bandwidth performance. Furthermore, the calculated SAR values are low and obey the limit imposed in the FCC and CNIRP regulations.

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