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DESIGN OF A TEXTILE ANTENNA WITH ARTIFICIAL MAGNETIC CONDUCTOR FOR ULTRA-WIDE BAND WIRELESS BODY AREA NETWORK APPLICATIONS

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ABSTRACT

This paper presents the design of a novel textile antenna with an artificial magnetic conductor (AMC) for Ultra-Wideband (UWB) Wireless Body Area Network Applications (WBAN).The design of a CPW antenna is chosen due to its ability to operate over a wide range of frequencies, with a bandwidth of 6.93GHz respectively. The proposed antenna is fabricated on a flexible felt substrate with permittivity 1.22, making it suitable for wearable applications. The incorporation of the AMC layer enhances the antenna's gain and improves its radiation performance, and stable impedance matching. The antenna is designed to operate in the frequency range of 3.1 to 10.6 GHz, which is suitable for UWB applications. The deformation analysis of the antenna with different bending radii at 8.364 GHz for 1gram where it meets the SAR standards of IEEE C95.3 has been measured using CST Microwave Studio tool.

1. INTRODUCTION

As people's demand for life and health, in order to achieve real-time monitoring, Wireless Body Area Network device needs are more and more extensive [1]. These devices can transfer human health status to medical sites, including body temperature, blood glucose, and electrocardiograms. The design of a wearable antenna faces many challenges. Prolonged exposure to high levels of electromagnetic waves can lead to harm to the human body due to the electromagnetic properties of human tissue. Therefore, a low levels of specific absorption rate (SAR) is a challenging task. Moreover, it is essential to consider the size and wearability of the antenna, as deformation may occur during the wearing process. Therefore, a flexible conformable antenna [2] has been chosen. In addition, antennas that preferentially consider unidirectional radiation, such as microstrip antennas or load floor, not only reduce SAR values and reduce the impact of the human body on antenna impedance characteristics. In order to design an antenna that meets the requirements for wear, an artificial magnetic conductor (AMC) is used as a reflector to reduce human SAR values [3–5]. In the literature [6, 7], AMC is mainly used to reduce the profile of antenna. In addition, in other articles, studies have shown that the radiation on the back side of the antenna loaded with AMC is reduced, and the gain in the radiation direction is enhanced [8]. However, in these studies, there are still some other problems that have not been solved, such as the overall size of the antenna and the unsatisfactory improvement of the back radiation. In order to maintain the advantages of the above literature research and overcome these shortcomings, based on the previous research, a CPW textile antenna placed above an AMC using felt as a substrate is fabricated and characterized, taking into consideration the orientation and position variations. The results show improved gain and directivity when the antenna is combined with AMC. The antenna has the advantages of small volume, low profile, and small radiation to the human body. The second part is about antenna and AMC design and analysis. The third part gives the SAR value when the antenna changes its performance when the antenna is bent and the radiation level of the antenna tothe human body. The fourth part gives the conclusion.

2. DESIGN AND SIMULATIONS:

2.1 Antenna design

The performance of printed antennas depends on the correct choice of the substrate on which they will be made.The substrate is not only a physical medium for the antenna but also affects its properties in terms of resonant frequency, bandwidth, and radiation efficiency. For printed antennas, the existing electromagnetic fields are inside the substrate.If the substrate admits losses, the efficiency of the antenna decreases.The thickness and the permittivity of the substrate also influences the bandwidth of the antenna. The right choice of the substrate must make it possible to satisfy both the mechanical constraints (flexibility) and the electrical stresses (tan d). A nonbrittle substrate having a low dielectric constant must be chosen to ensure better efficiency, wide bandwidth, and good radiation from the antenna. Thus, we have chosen Felt (ε_r=1.22 and tanδ= 0.016), as our substrate. Felt is a hardware that is usually used for the realization of patch antennas. However, this substrate is very widespread in the market existing in several dimensions and at a low cost. By treating this fabric as a conventional textile, it can be easily cut and sewn to create both the ground plane and patch of the textile antenna.The proposed wearable antenna is powered by a coplanar transmission line with a 50 Ω impedance matching and is optimized with CST Microwave 3D electromagnetic simulator, as shown in Figure 1.

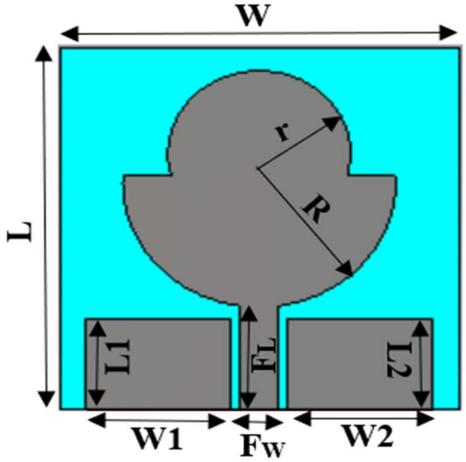

Figure 1 Geometry of the Proposed Antenna fed by CPW.

Table 1 Dimensions of the proposed antenna.

S.no	Components	Parameter	Value	Thickness(mm)
1.	Substrate	(L*W)	(24*24)	1
2.	Patch	R,r	8.2,5.5	0.5
3.	Feed	(F_L*F_W)	(11*2.4)	0.5
4.	Ground1	(L_1*W_1)	(6*8.7)	0.5

5.	Ground2	(L_2*W_2)	(6*8.7)	0.5

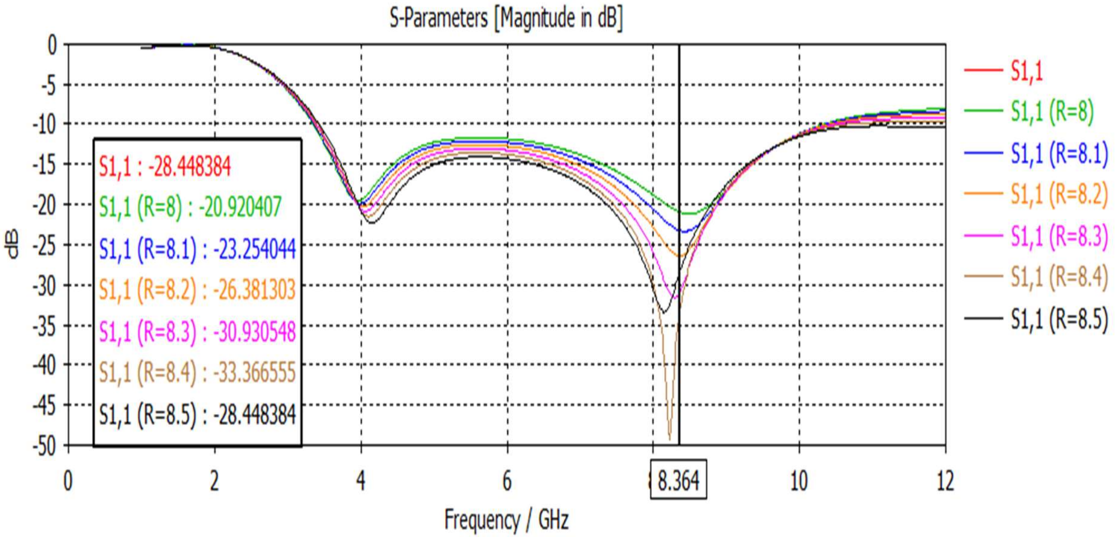

Figure 2 Parametric analyses S_{11} of the proposed antenna.

To ensure that the antenna operates within the desired ultra-wideband (UWB) frequency range, we conducted a parametric sweep by varying the patch radius. After analyzing the results, we determined that a patch radius of 8.2 would be optimal for achieving the desired frequency range. Consequently, we set the patch radius to 8.2, which allowed the antenna to resonate at this radius and operate within the perfect UWB range as shown in Figure 2.

3. AMC DESIGN

We propose to perform a frequency study on the phase of the reflection coefficient of a dual-band AMC based on a double form **“I”** as shown in Figure 3.

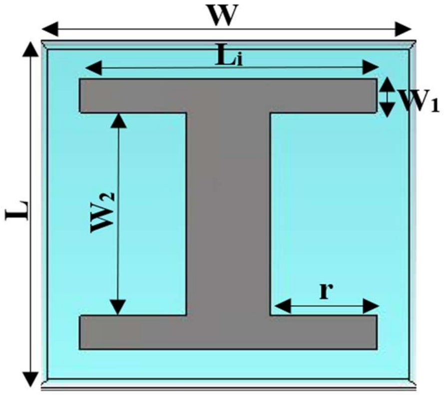

Figure 3 Geometry of proposed AMC Unit Cell.

Table 2 Dimensions of the AMC unit cell.

Parameters	**Values (mm)**
W	20
L	20
L_i	16
W_1	2

L_1	12
R	5.7

To study the various modes of operation, we draw the surface currents on the metallization of the I-patches for each resonance of the AMC where the phase of the reflection coefficient is zero. We then use the well-known electrical model to describe the behaviour of cells with via. In the model shown in Figure 4, we consider a capacitance C_1 and two inductances L_1 in parallel with an inductance L_2.

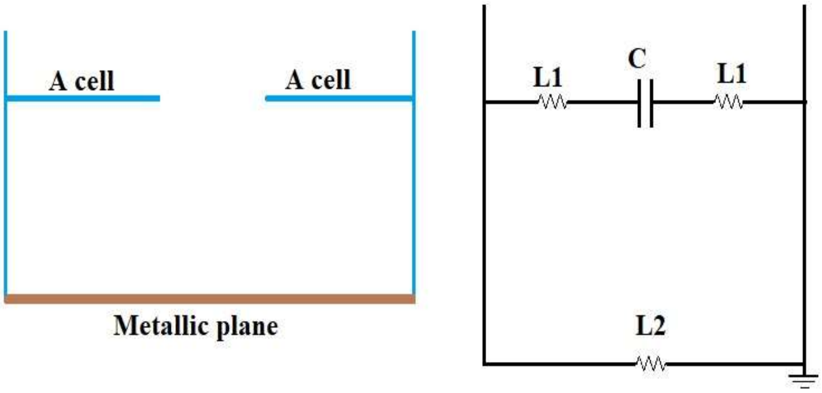

Figure 4 Equivalent circuit of **"I"** shaped AMC Unit Cell.

The capacitance C_1 models the gap between two adjacent cells. The inductance L_2, which is constituted of a metal plane under the periodic surface, varies as a function of the height of the cell and the metal plane while L_1 models the cell. This equivalent electrical circuit is a simple parallel LC resonator and the resonance frequency can, therefore, be readily obtained. The Unit cell of the AMC size and the phase of the reflection coefficient are achieved from 1 to 7 GHz as shown in Figure 5 where the AMC counts two modes with resonance frequencies of 6.25GHz and8.36 GHz. The frequency bands are deduced by the ± 90 variations around the 0° phase values.

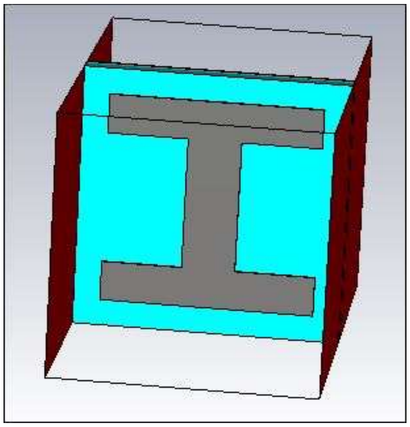

Figure 5: Tilt view of constructed AMC Unit Cell.

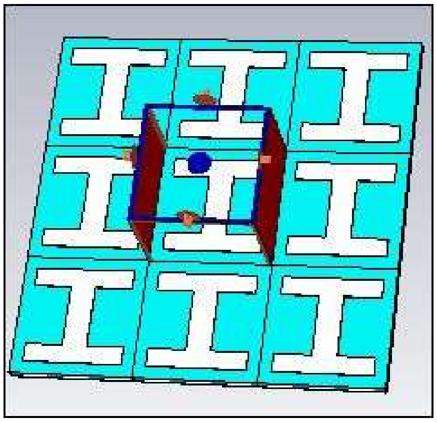

Figure 6: 3*3 AMC Unit Cell.

4. ANTENNA WITH AMC

To obtain better radiation performance, we have used a HIS AMC surface and a double I-shaped AMC.Theoretically, we can place an antenna directly on the AMC plane at different resonance frequencies, which is not feasible in practice. For an optimal operation of the AMCantenna assembly, a certain distance must be maintained between the two elements. Thus, a foam substrate is added between the antenna and the AMC as seen in Figure 8.

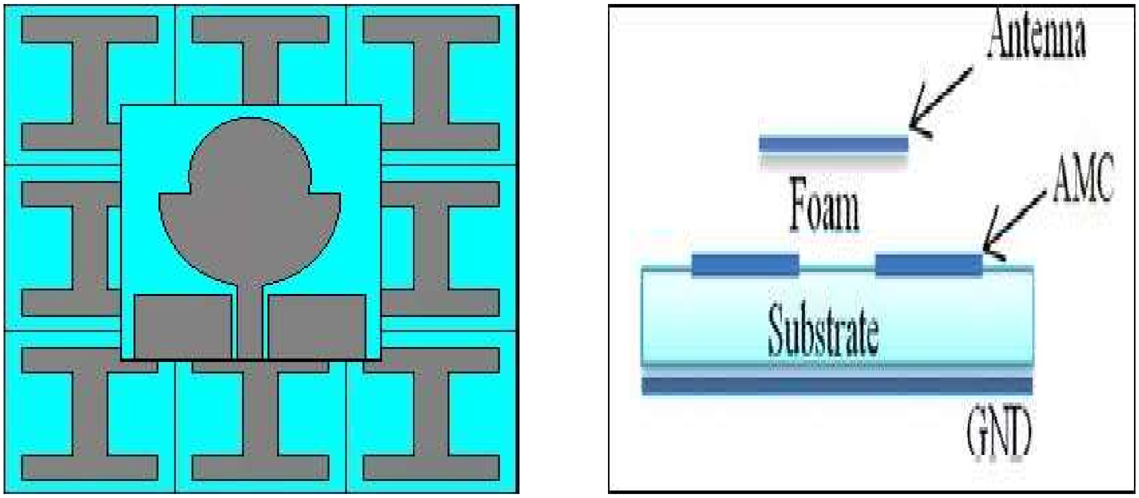

Figure 7: Reflection coefficient of the AMC antenna for different cells matrices.

5. RESULT ANALYSIS

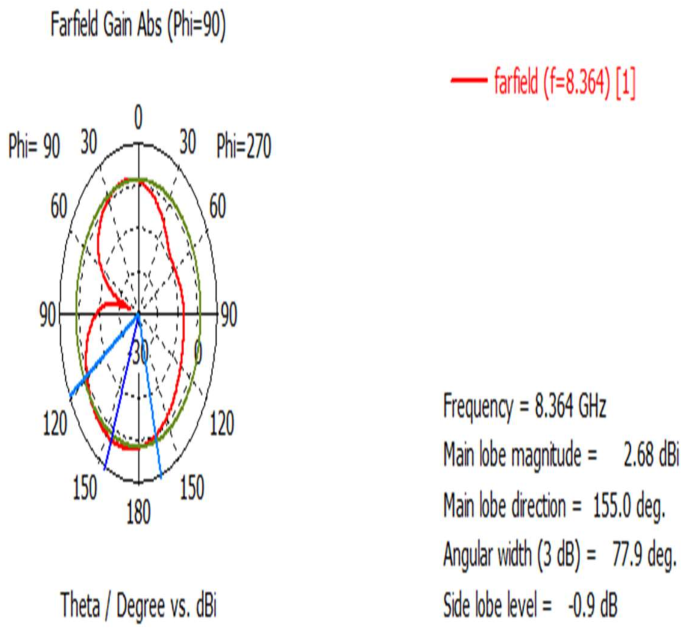

Figure 8: Gain of the proposed antenna at 8.364GHz.

Figure 2 displays the S11 parameters of the evolution of proposed antenna, indicating resonance in the Ultra-Wideband Frequency range, while Figure 8 illustrates the antenna's gain of 2.68db.

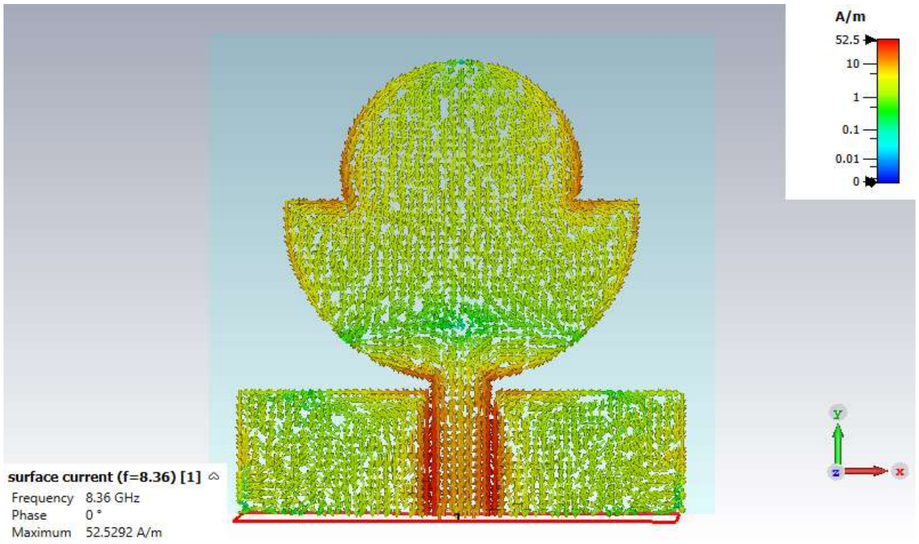

Figure 9: Surface Currents at 8.364GHz.

Figure 5 illustrates that the proposed antenna operates by generating surface currents at both the feed line of the patch and the edge of the coplanar waveguide (CPW), which in turn leads to efficient radiation within the patch. The antenna is fed using coplanar transmission, allowing for the effective transfer of electromagnetic energy.

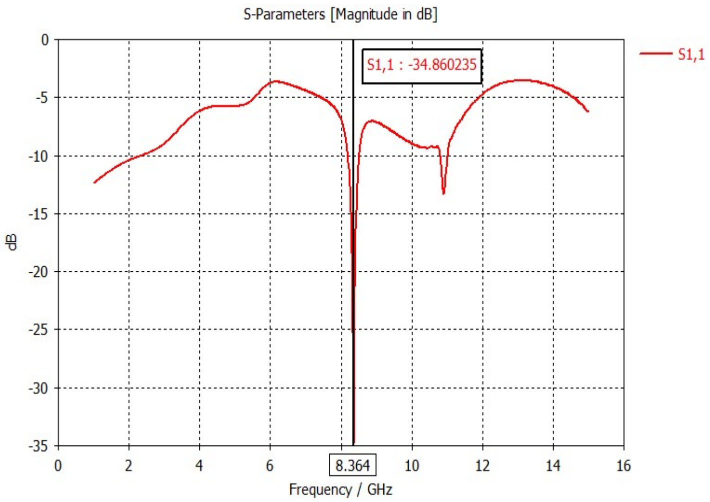

Figure 10: S_{11} of AMC Unit Cell at 8.36GHz.

From Figure 2 and Figure 10 the correlation between the S11 parameter of an antenna and an Artificial Magnetic Conductor (AMC) matches i.e. 8.364GHz, it indicates that the design of the AMC is effectively reducing the reflections from the antenna and improving its performance. Specifically, it means that the AMC is minimizing the amount of energy that is reflected back to the antenna and instead allowing more of the energy to be radiated into space.

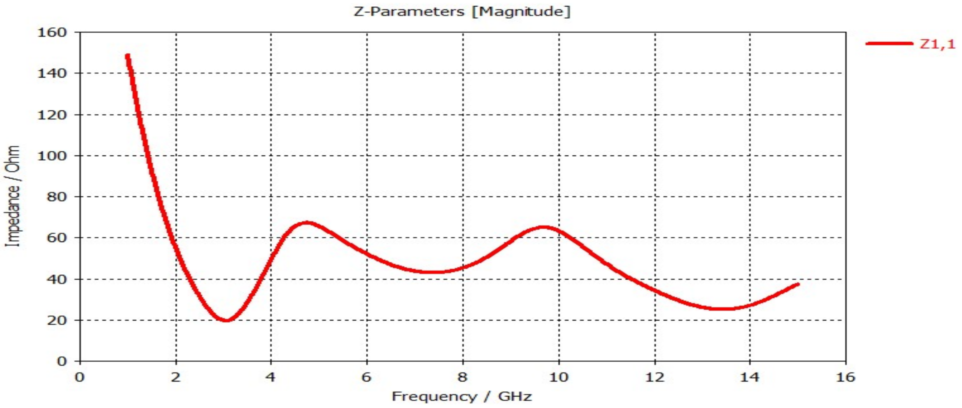

Figure 11: Impedance at 8.36GHz of AMC Unit Cell.

The AMC is designed to reflect the waves in such a way that they interfere constructively with the waves emitted by the antenna, resulting in improved radiation efficiency and a more directional radiation pattern. To achieve this constructive interference and minimize reflections, the AMC must be designed with an impedance that matches that of the transmission line or device it is connected to. In most RF systems, this impedance is 50 ohms as shown in Figure 11. A matching impedance ensures that the energy is efficiently transferred from the transmission line or device to the AMC and then to the antenna, without significant reflections or loss of energy.

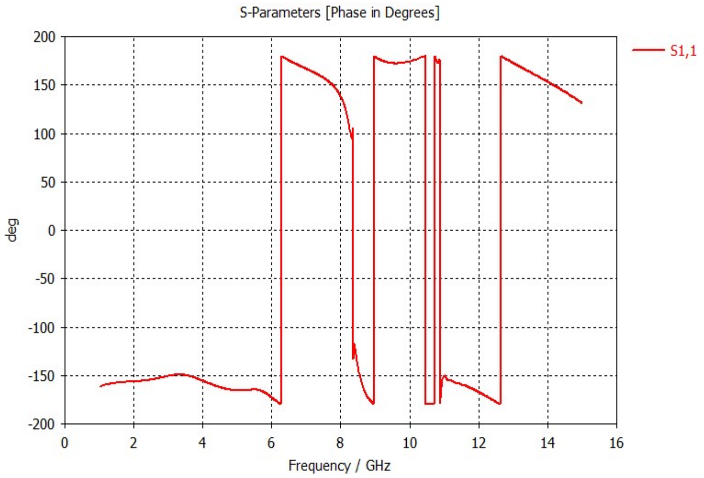

Figure 12 Phase reflection coefficient of AMC Unit Cell.

Figure 12 describes the phase shift that occurs when a wave is reflected from the surface of the AMC, relative to the incident wave.

5.1 Bending Analysis of Antenna

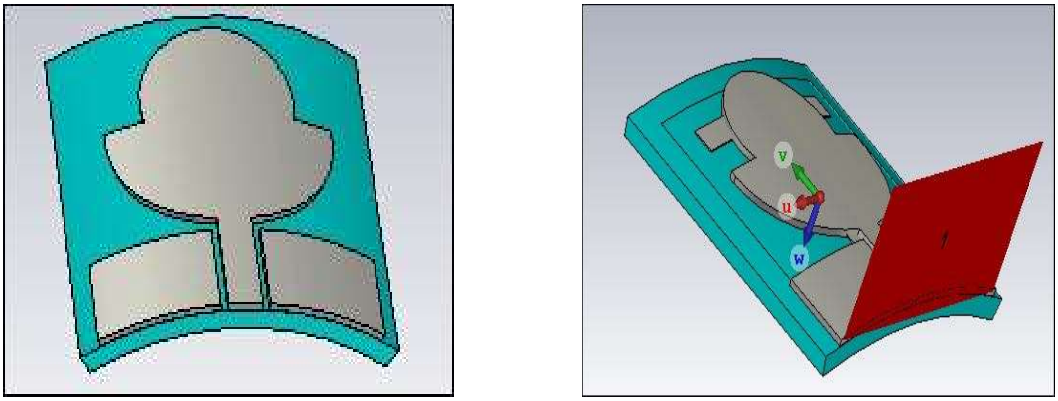

Figure 13 Bending analysis of antenna at different radii.

Bending analysis of an antenna involves studying the effect of mechanical bending on its electrical performance. When an antenna is bent, its physical structure is deformed, which can cause changes in its resonant frequency, radiation pattern, and impedance matching. The proposed antenna model is subjected to various bending radius and forces, and the resulting changes in the antenna's performance are analyzed. Bending analysis is particularly important for flexible and conformal antennas, which are designed to be bent or molded into different shapes. By understanding the effects of bending on the antenna's performance, we can optimize its performance for specific applications, such as wearable devices or curved surfaces.

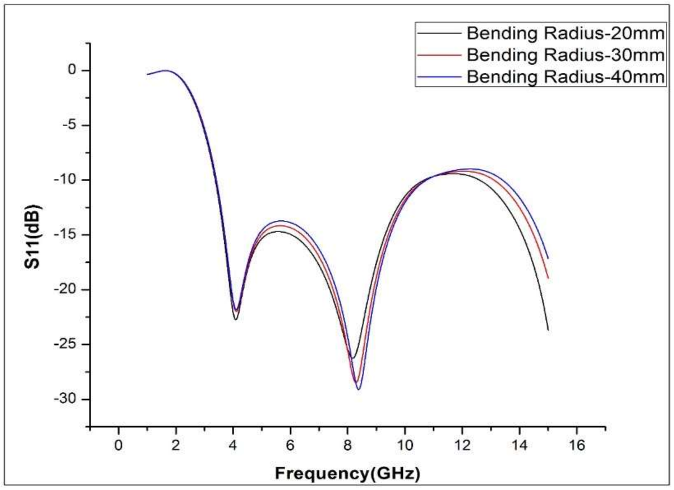

Figure 13 S11 of Bending Analysis of Antenna at different radii.

5.2 SPECIFIC ABSORPTION RATE

SAR stands for Specific Absorption Rate, which is a measure of the rate at which electromagnetic energy is absorbed by the human body when exposed to an electromagnetic field. In the context of an antenna, SAR is a measure of how much electromagnetic energy is absorbed by the human body when the antenna is transmitting. Specific absorption rate is the important parameter for analysis of antenna for on body performance, where figure 15 shows that for 1g the proposed design is below the IEEE standards which does not affect with its radiation

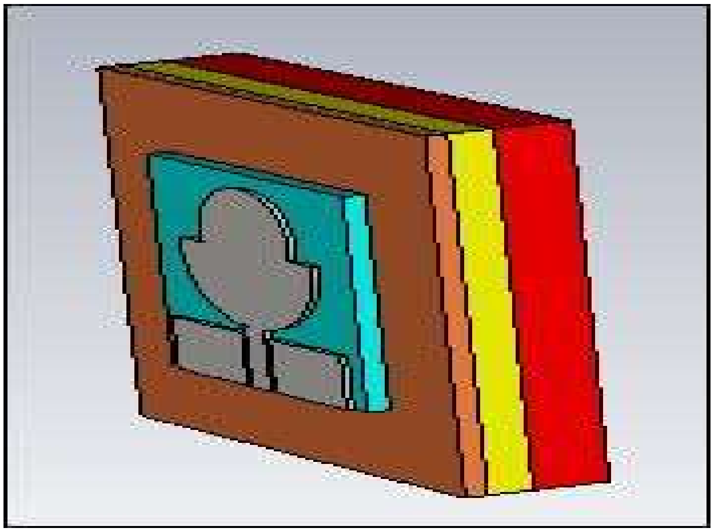

Figure 14 Phantom model of proposed antenna

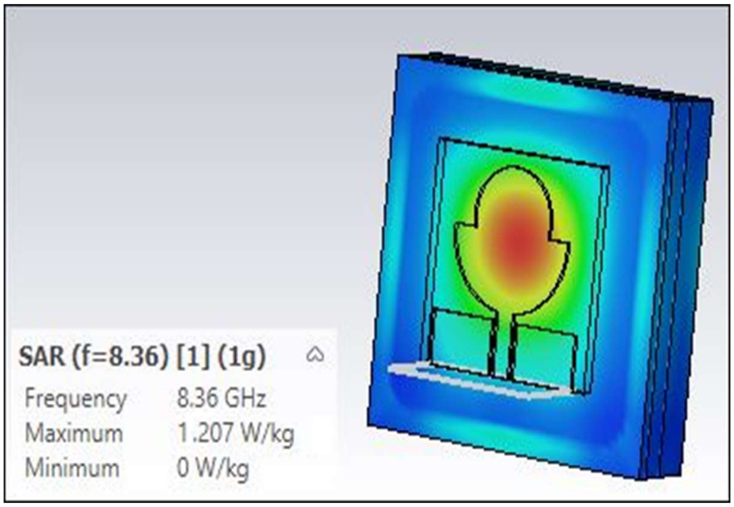

Figure 15 Specific Absorbtion Rate at 1.207 W/kg for 1 gram

Table 3 Compartive analysis of the proposed design with previous work.

Ref. No./Year	Dimensions (mm)	Substrate Material	Permittivity	Resonate Frequency (GHz)	S_{11} (dB)	Gain (dBi)	Bandwidth (MHz)
[11]/2018	32x39	Felt	1.22	5.8	-20	9.9	---
[12]/2019	78x78	Denim	1.6	2.42	-23.9	7	42
[13]/2020	100x100	Felt	1.22	2.45	-18	5.8	119
[14]/2021	75x80	Jean/ Cotton	1.67	2.4	-16.3	4.3	45
[15]/2022	80x80	Cotton	1.51	2.4	-16.27	5.14	80
Proposed work	24x24	Felt	1.22	8.364	-26.38	2.67	69.3

6.CONCLUSION

In this work, a novel textile antenna is proposed to function at the UWB band.It is fully flexible with Felt as substrate.The antenna was designed using an artificial magnetic conductor (AMC) to improve its performance and reduce the impact of human body interference.The antenna is simulated at 8.364 GHz for WBAN applications where it meets the SAR standards of IEEE C95.3.The results of the textile antenna with AMC had improved radiation characteristics with 2.67 dBi gain and reduced the impact of human body interference compared to traditional antennas.

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