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A TEXTILE WEARABLE MONOPOLE ANTENNA WITH AMCARRAY STRUCTURE FOR IOMT APPLICATION

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Abstract : This work introduces a dual port textile monopole antenna with coplanar waveguide (CPW) fed and enhanced gain to be utilized in the wearable Internet of Medical Things (IMoT) applications to support wireless wearable sensors for vital sign monitoring on the human body. The proposed antenna was fabricated using a jeans material substrate. This antenna has good characteristics for wearable communication applications, which is light in weight, small in profile, and comfortable to wear. The proposed antenna was operated at 2.4, 3.5, and 5.8 GHz for industrial, scientific, and medical (ISM), 5G, and wireless local area network (WLAN) applications. A compact antenna design was specifically engineered to suit the rigorous standards demanded by intricate subsystems operating in those frequency bands for IoMT and 5G applications. The proposed MIMO antenna is designed and simulated using CST MWS 2019 software**. Key words:** Artificial magnetic conductor (AMC), coplanar waveguide (CPW), Internet of Medical Things (IoMT), industrial, scientific, and medical (ISM), wireless body area network (WBAN).

1. INTRODUCTION

An Antenna is a transducer, which converts electrical power into electromagnetic waves and vice versa. An Antenna can be used either as a transmitting antenna or a receiving antenna. A transmitting antenna is one, which converts electrical signals into electromagnetic waves and radiates them. A receiving antenna is one, which converts electromagnetic waves from the received beam into electrical signals. In two-way communication, the same antenna can be used for both transmission and reception. Antenna can also be termed as an Aerial. Plural of it is antennae or antennas. Now- a days, antennas have undergone many changes, in accordance with their size and shape. There are many types of antennas depending upon their wide variety of applications.

In the field of communication systems, whenever the need for wireless communication arises, there occurs the necessity of an antenna. Antenna has the capability of sending or receiving the electromagnetic waves for the sake of communication, where we cannot expect to lay down a wiring system. In order to contact a remote area, the wiring has to be laid down throughout the whole route along the valleys, the mountains, the tedious paths, the tunnels etc., to reach the remote location. The evolution of wireless technology has made this whole process very simple. Antenna is the key element of this wireless technology.

The sole functionality of an antenna is power radiation or reception. Antenna (whether it transmits or receives or does both) can be connected to the circuitry at the station through a transmission line. The functioning of an antenna depends upon the radiation mechanism of a transmission line. A conductor, which is designed to carry current over large distances with minimum losses, is termed as a transmission line. For example, a wire, this is connected to an antenna. A transmission line conducting current with uniform velocity, and the line being a straight one with infinite extent, radiates no 1 power. For a transmission line, to become a waveguide or to radiate power, has to be processed as such. If the power has to be radiated, though the current conduction is with uniform velocity, the wire or transmission line should be bent, truncated or terminated. If this transmission line has current, which accelerates or decelerates with a time varying constant, then it radiates the power even though the wire is straight. The device or tube, if bent or terminated to radiate energy, then it is called as waveguide. These are especially used for the microwave transmission or reception.

2. LITERATURE REVIEW

Wearable antennas should have some specifications for optimal performance; such as lightweight, compact size, low cost, high gain and efficiency, maintenance-free, robust, low specific absorption rate (SAR), and that offer comfort to wearers [12], [13]. The substrate has changed over time moving from traditional hard composites to more recent flexible materials and finally to textiles, where the electro textile materials have found huge use with the evolution of wearable antennas where they add to the design a higher degree of flexibility and robustness [14], [15].

Textiles as a material for a wearable antenna are becoming more appealing and challenging for scientists in different applications because it has low weight and high flexibility; in addition, it is easy to incorporate into clothing and is extremely comfortable to wear [11]. A textile-based structure with several requirements, such as low electrical resistance, flexibility, and deformability, should be used for a wearable antenna, polyester cloth substrate, latex, polyimide, jeans cotton, wool felt, and polar fleece. For the conductive part nylon conductive textile "Nora-DellCR" fabric used, conductive textile [embroidered using332-strand silver-coated Amberstrand fibers (e-fibers)] used in literature..

Ref.	AntennaSize (mm^2)	Operating frequency(GHz)	Substrate	Gain without AMC (dBi)	AMC Size (mm^2)	GainWith AMC (dBi)
[16]	48.4×42.5	1.8, 2.4, 3.5	Polymide	NR	124×155	10.1, 2.86, 5.06
[17]	43×55	2.4, 3.5, 5.8	Felt	0.79, 0.57,3.78	75×60	1.12, 1.01, 5.65
[18]	40×40	2.4	RT 5800	NR	120×120	3.09

Table 1: Literature summary of reported antennas for IoMT application

3. PROPOSED METHODOLOGY

In this we propose a four-port/two-resonator slot antenna array with a dual polarized function for multiple-input-multiple-output (MIMO) 5G mobile terminals. The design is composed of four dual-polarized square-ring slot radiators fed by pairs of microstrip-line structures. The radiation elements are designed to operate at 3.6 GHz and are located on the corners of the smart phone PCB. The square ring slot radiators provide good dual- polarization characteristic with similar performances in terms of fundamental radiation characteristics. In order to improve the isolation and also reduce the mutual coupling characteristic between the adjunct microstrip-line feeding ports of the dual-polarized radiators, a pair of square-ring/open-ended parasitic structures is embedded across each square-ring slot radiator.

3.2 DESIGN METHODOLOGY:

This textile wearable antenna was created to be attached to clothing or carried off body on items. The novelty of the suggested antenna is first, and it is implemented on a thin flexible conductive and dielectric material that can easily bend around the human body and be attached to clothes. Second, it achieved a triple band for IoMT and 5G applications. Third, it introduced high isolation from human tissue and complies with safety requirements for medical applications. Finally, it has a low SAR level, high gain, and directivity compared to other wearable antennas on textiles.

3.2.1 TRIPEL BAND MONOPOLE ANTENNA: Behind the characteristics of the textile antenna in flexibility and comfort ability, it has a low dielectric constant, which can lessen the antenna's surface wave losses. Meanwhile, the application of wearable antennas has to be incorporated into the human body. However, the electrical properties of biological tissues and the shape of the human body have an impact on the antenna's performance. Traditional solid materials with a high dielectric constant are failed to meet these criteria, but materials with a low dielectric constant can fulfill all of these demands. Also, low-dielectric materials have a significant impact on bandwidth expansion. The decision was made to use textile flexible felt out of a variety of substrates, which satisfied durability, high flexibility, robustness, thermal endurance, low weight, and comfortability in wearing, in addition to easy integration, wear resistance, and low cost, where it has a 28 thickness of 1.5 mm with a dielectric constant of 1.2 and a dielectric loss tangent of 0.044.

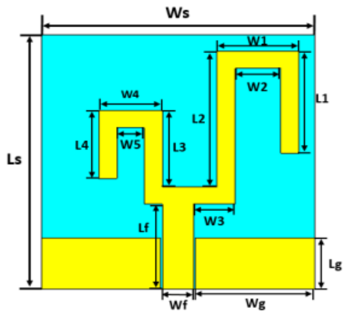


Fig. 3.2 The Proposed triple-band monopole antenna configuration

Table 3.1 Dimensions of triple-band antenna design

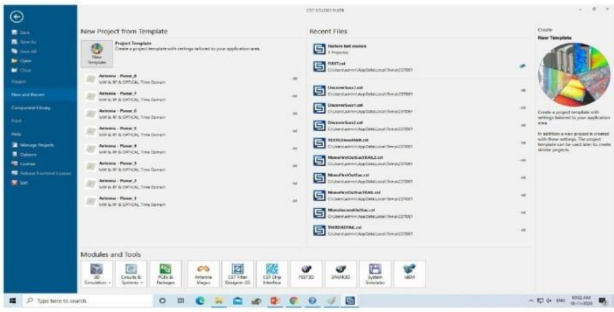
W1	9	Wf	3.4	Ws	30
W2	5	Lf	10	L1	12
W3	4.6	Wg	13.1	L2	16
W4	7	Lg	6	L3	9
W5	3	Ls	30	L4	8

3.2.2 DESIGN EVALUTION:

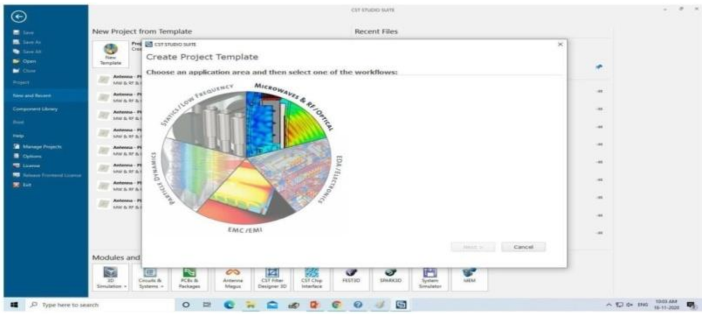
For some applications, the triple-band operation with particular resonating frequencies and bandwidth is essential. Fig. 3.2 depicts the suggested triple-band planar monopole antenna's configuration geometry, which consists of a classical square substrate with two rectangular grounds staked on both sides of the radiator feedline. The design steps were started from the square substrate with dimensions 28.5 × 28 mm, with a simple feedline and two lines as a monopole, in addition to a partial ground

3.2.3 DESIGN STEPS IN CST MW STUDIO:

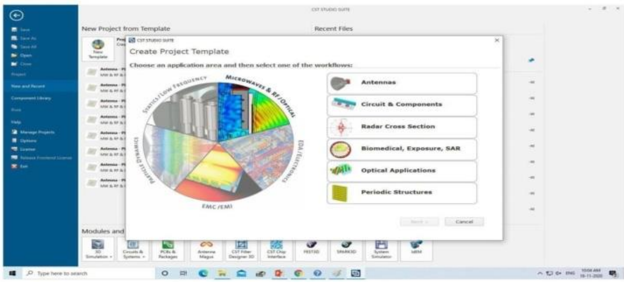
Step 1: Open CST Suite and Click on New Template



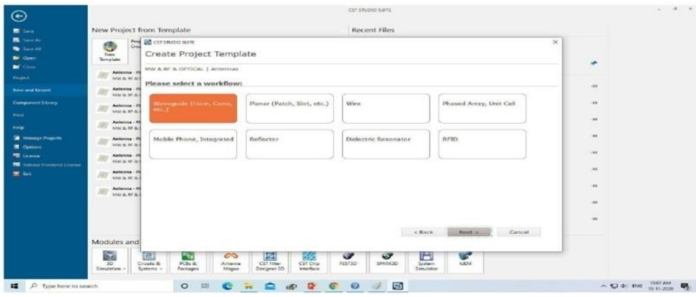
Step 2: Select MICROWAVES & RF/OPTICAL Project Template



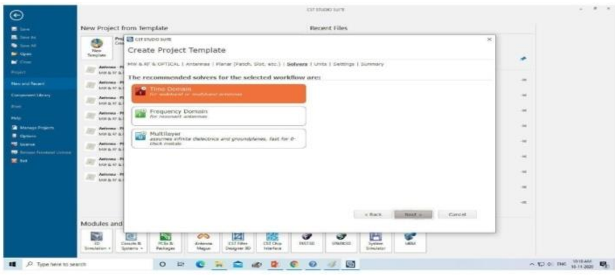
Step 3: Choose Application Area as Antenna



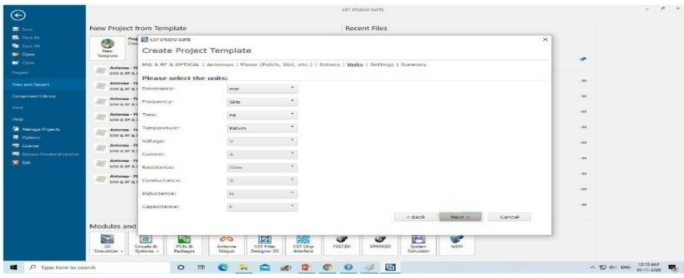
Step 4: Select a work flow as a Planar



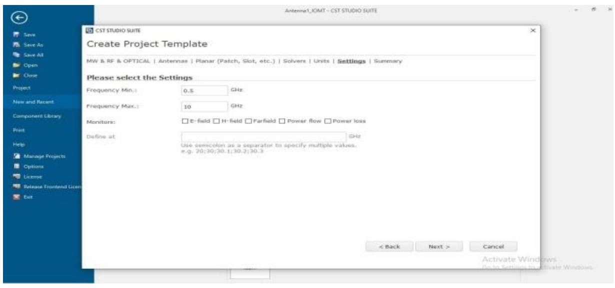
Step 5: Select Time Domain Solver



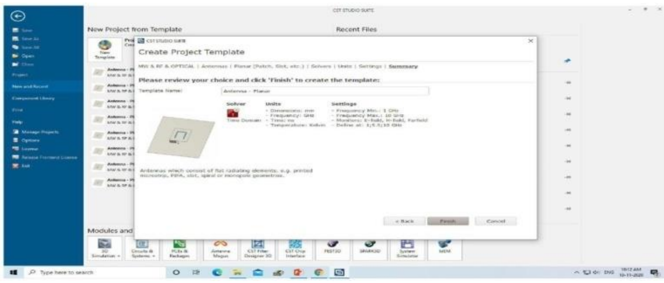
Step 6: Select the Units



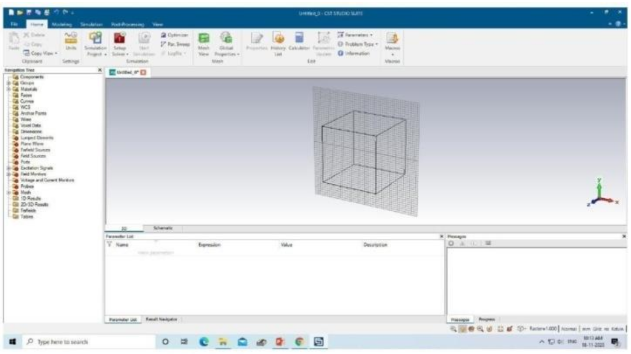
Step 7: Select Settings, f_{min} =0.5 GHz and f_{max} =10 GHz



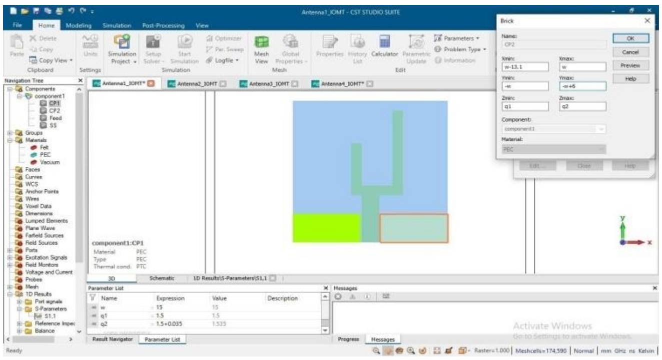
Step 8: Give the template name and click on Finish



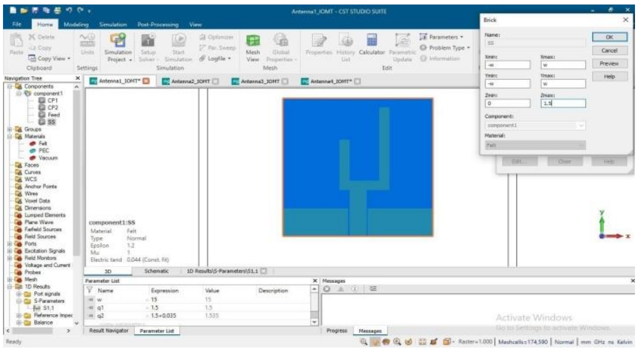
Step 9: Arrange the mesh and bounding



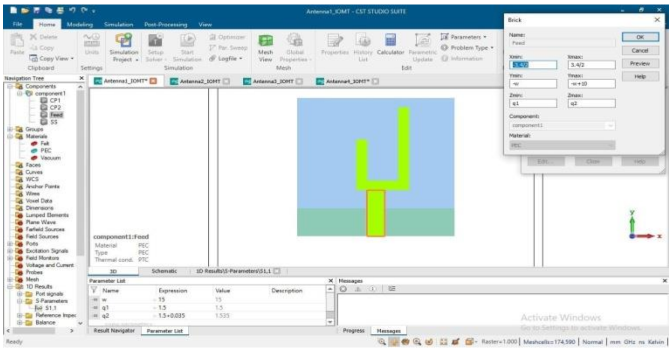
Step 10: Create the ground (use solid Brick)



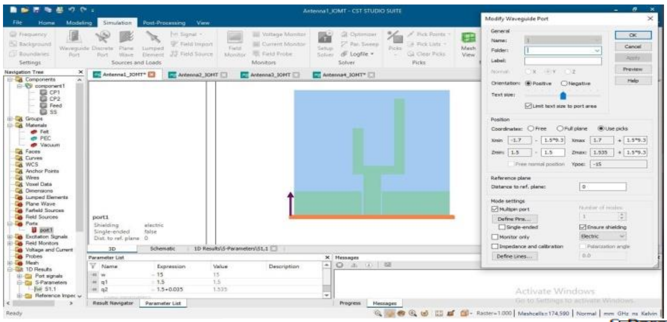
Step 11: Create the Substrate



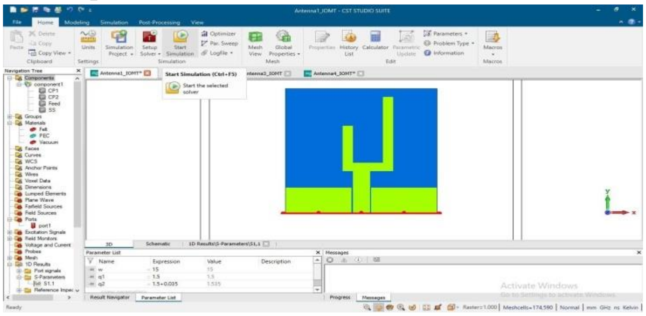
Step 12: Create the Patch

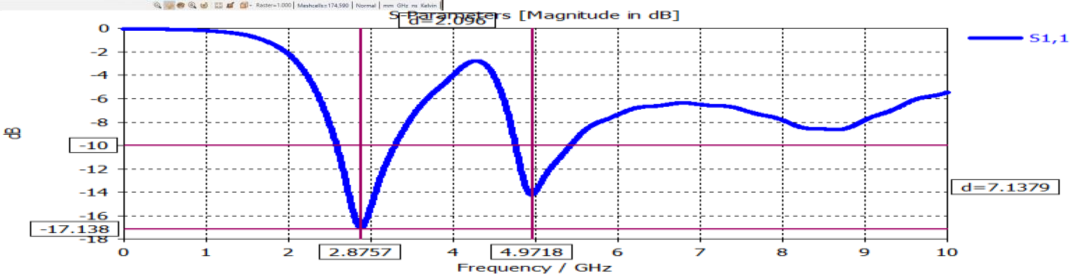


Step 13: Define the wave guide port



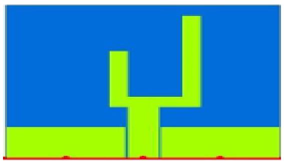
Step 14: Go to HomeStart Simulation



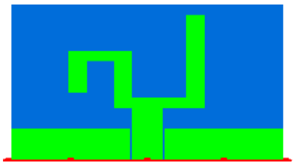


Step 15: Analyze the Results

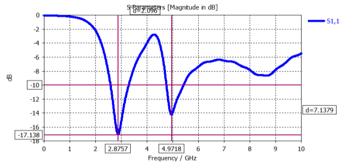
The obtained result from antenna-1 is not satisfactory. From literature, we came to know that, increasing electrical length of the resonator of antenna-1 can alter its performance by affecting the distribution of currents and electromagnetic fields in the antenna structure.



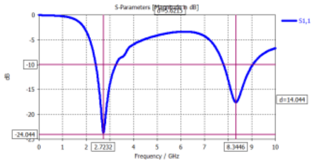
Antenna-1



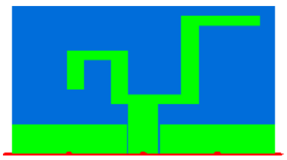
Antenna-2



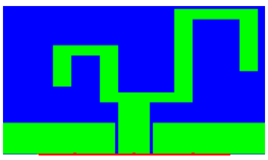
S_{11} -parameter Antenna-1



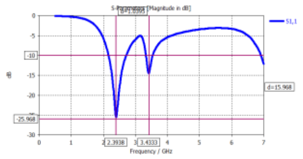
S11-paramete Antenna-2



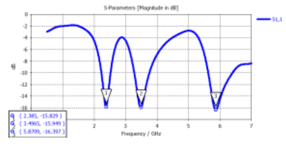
Antenna-3



Antenna-4



S_{11} -parameter Antenna-3



S11-paramete Antenna-4

The optimized design presented resonances centered around 2.4 GHz, 3.5 GHz, and 5.8 GHz , covering a bandwidth of 340 MHz, 375 MHz, and 790 MHz with VSWR maintained below 2, reaching as low as 1.5, indicative of good impedance matching.

3.2.2 TRIPLE-BAND AMC DESIGN:

To boost antenna gain and directivity with decreased back radiation for human safety, the triple-band AMC unit cell is designed as a reflector in this section, which produces a 0◦ reflection phase to an incident wave in a specific frequency band. Particularly, electromagnetic waves emitted by the antenna have the potential to be harmful to body tissues. To adapt this antenna for wearable technology; within the limits 41 of human health, the AMC unit cell structure aims to lessen the SAR effect. The design of the AMC unit cell structure takes into account the antenna’s reflection coefficient at the requisite frequency bands, where the reflection coefficient is a factor that establishes the power reflected from the antenna input due to a mismatch in the antenna’s impedance, and it is used to assess antenna impedance matching and operating frequency band in antenna design.

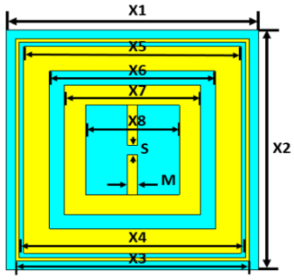
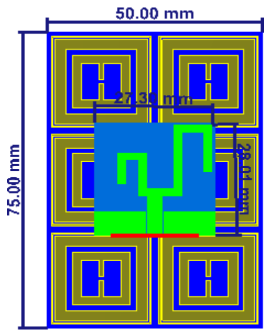


Fig. 3.22 Configuration of the proposed triple-band AMC unit cell

L	50	X5	21.5
W	75	X6	16.4
X1	25	X7	13.5
X2	25	X8	9.3
X3	23.1	S	1
X4	22.4	M	1

Table 3.2 Dimensions of triple-band AMC unit cell design

Besides, the benefits of the AMC array, sometimes, may it have a minor negative impact on how well the antenna functions, especially in the case of the prototype, the antenna was fabricated manually, which may lead to some shift in the frequency band. The simulated bandwidth at the three desired frequency bands ranged from 2.2 to 2.53 GHz, 3.3 to 3.7 GHz, and 5.65 to 6.42 GHz, respectively. Based on the outcomes of the simulation it is established that the proposed antenna integrated with the AMC array structure achieves high agreement between simulated results and has a wide frequency bandwidth at three frequencies band, which covers the center of selected frequency operation bands.



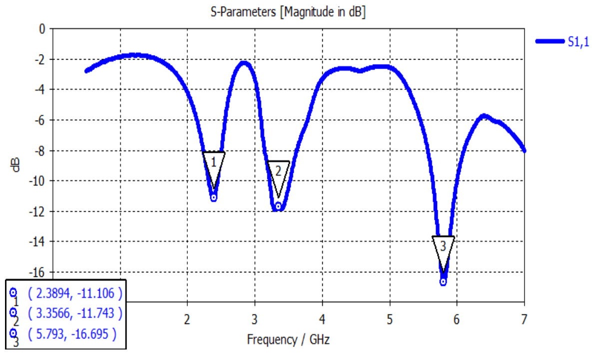
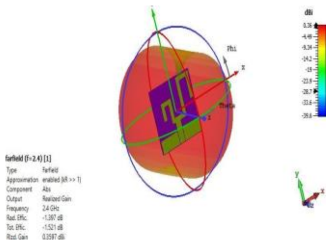


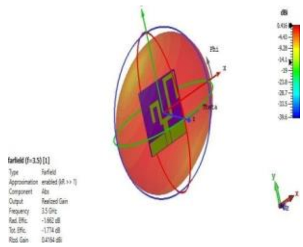
Fig.3. 23 Configuration of the proposed triple-band antenna integrated with 2 × 3AMC array&S11-parameters

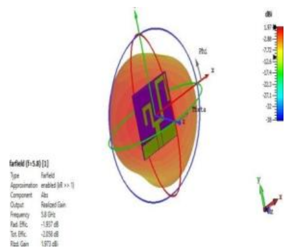
1. RESULTS AND DISCUSSIONS

4.1 SIMULATION RESULTS:

Due to the antenna being designed for wireless body area network (WBAN) use, the antenna was positioned over a human body model to get the results and to make sure the antenna is safe in use. Fig.4.1-4.3 shows the proposed antenna's simulated gain results at the triple bands. Fig.4.4-4.6also illustrated the simulated gain result with an AMC array structure at the specified operating







frequency bands.

Fig. 4.1 Realized Gain of 2.4 GHz Antenna Fig. 4.2 Realized Gain of 3.5 GHz Antenna Fig.4.3 Realized Gain of 5.8 GHz Antenna

The 3D views of the antenna radiation patterns at 2.4 GHz, 3.5 GHz, and 5.8 GHz are displayed in above Fig. 4.1-4.3. As shown, same radiation performances with linear polarizations and also gains 0.36 dBi, 0.416 dBi, and 1.97 dBi, are obtained for the proposed triple band antenna design. It can be seen that the designed antenna provides dumbell-shaped radiation patterns suitable to cover the top and bottom side of the substrate which can increase the radiation coverage of the 5G band antenna design.

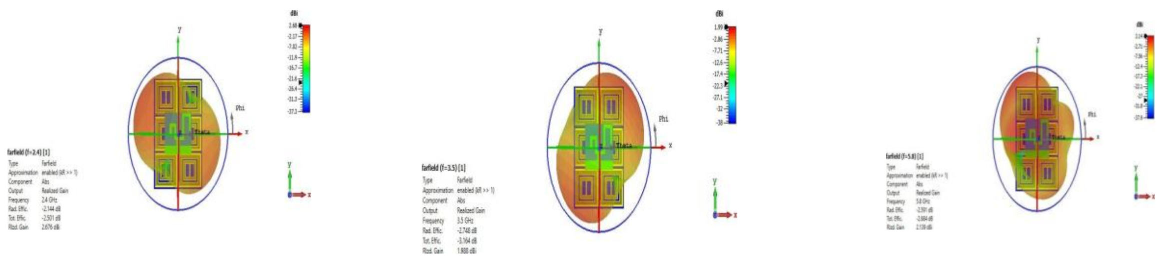


Fig. (4.4,4.5, 4.6) Realized Gain With AMC for 2.4 GHz o 3.5 GHz and 5.8 GHz Antenna

The 3D view of the proposed triple band antenna with AMC structure is displayed in Fig. Fig.4.4-4.6. The proposed design is arranged on a felt dielectric with permittivity 1.5 and loss tangent 0.044 which has an overall dimension of 75 × 50 mm2. The triple 46 band antenna with AMC structure with the reduced size of 28.01 × 27.36 mm^2. Clearly, the radiation elements have similar return loss performances providing high gains of 2.68 dBi, 1.99 dBi, and 2.14 dBi at 2.4 GHz, 3.5 GHz, and 5.8 GHz, respectively.

4.2 SAFETY ASSESMENT:

Specific Absorption Rate (SAR) is a measure of how transmitted RF energy is absorbed by human tissue. The SAR is calculated by averaging (or integrating) over a specific volume (typically a 1 gram or 10 gram area). According to the IEEE C95.1-2019 standards, the SAR value for 1g/10g of human tissue should be less than 1.6/2.0 W/kg [13]. For an input power of 0.01 W, the simulated SAR values for 1g of tissue were found to be 0.522 W/Kg at 2.4 GHz, and 0.366 W/Kg at 5.8 GHz.

4.3 FABRICATION AND MEASUREMENT RESULT:

As illustrated in Fig. 4.3, a prototype of the triple band monopole antenna was fabricated and its fundamental characteristics were tested in the Antenna Laboratory at the SRM University, Chennai. As can be seen, the S-parameters of the antenna including S11 and S21 characteristics were measured using the Keysight vector network analyzer. The measured S-parameter results of the prototype are displayed in Fig. 4.4. As illustrated, the antenna provides very good impedance matching around 2.4 GHz, 3.5 GHz, and acceptable impedance matching at 5.8 GHz. In addition, compared with the simulations, it can be confirmed that there is a good agreement between them.

4.4 PERFORMANCE COMPARISION:

Table 4.1 summarizes the geometrical dimensions, operating band, and gain without and with AMC of recently reported antennas. It shows that, while subject to their clinical applicability, overall size, and gain without and with AMC, the recently reported antennas still need to be low- profile or compact compared to the proposed textile monopole antenna.

Table 4.1: Comparative Analysis of the proposed antenna with the reported antennas

Ref.	**Antenna Size (mm^2)**	**Operating frequency (GHz)**	**Substrate**	**Gain without AMC (dBi)**	**AMC Size (mm^2)**	**GainWithAMC (dBi)**
[16]	48.4×42.5	1.8, 2.4, 3.5	Polymide	NR	124×155	10.1, 2.86, 5.06
[17]	43×55	2.4, 3.5, 5.8	Felt	0.79, 0.57,3.78	75×60	1.12, 1.01, 5.65
[18]	40×40	2.4	RT 5800	NR	120×120	3.09
Proposed	**28 × 27.3**	**2.4, 3.5, 5.8**	**Felt**	**0.36, 0.416, and 1.97**	**75×20**	**2.68, 1.99, and 2.14**

V. CONCLUSION:

This work proposed a flexible low-profile triple-band wearable antenna for IoMT application that is integrated with an AMC array structure at its back. The antenna’s top side, which is responsible for radiation, has a monopole with mender line geometry, and the two rectangular grounds on either side of the feedline are all attached to a felt substrate. On the other hand, a 2 × 3 AMC array structure is suggested and implemented on the antennas back with a space of 3 mm, which decreases back radiation and raises the antenna’s front to back ratio (FBR) value. And it can be concluded that, the proposed antenna has a compact size with a simple configuration, and it operated at 2.4GHz, 3.5GHz and 5.8GHz which covers 2.322GHz-2.438GHz, 3.206GHz–3.531GHz and 5.648GHz-6.012GHz bands with radiation efficiency of 94.31%, 89.45% and 82.25% and high level of impedance matching, where VSWR is less than 2 and the return loss is better than -10 dB. The developed antenna has a low SAR level, high gain, and directivity due to the AMC array structure at its back.

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