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A LOW SAR VALUE CIRCULAR-BASED FEEDING OF CPW WITH A MONOPOLE STRUCTURE WEARABLE ANTENNA FOR WIRELESS BODY AREA NETWORK (WBAN) APPLICATIONS

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ABSTRACT

In this paper, The wideband, low-profile, semi-flexible antenna for wearable technology is presented and covers an industrial, scientific, and medical (ISM) frequency bands. The investigation and analysis focuses on the free space and on-body antenna performance parameters for the proposed antenna with the operating range of 2.45 to 5.8 GHz. The circular construction with triangular slots attains dual-band applications. The antenna's dimensions are 39 x 29 x 0.2 and it is made of flexible polyimide with a loss tangent of 0.008. It has a dielectric constant of 3.5. The antenna's bending analysis is done to determine how flexible it is. The suggested antenna has fractional bandwidths of 41% and 28%, covering the frequency ranges 2.3-3.5 and 5.1-6.8 GHz. The patterns in which the antenna is provided under omnidirectional and stable dipole arrangements. The final antenna model has the frequencies are 2.7GHz and 6.1GHz with gain peak values approximately 2.4 dBi, 4.8 dBi with frequency variation of 2.7 Hz and 6.1 GHz associated to efficiency for reflected region sampled at 2.7 GHz, 6.1 GHz reaching 79%, and 85%. The simulation findings demonstrate that bending the antenna has no influence at all on the bandwidth, efficiency, gain, or reflection coefficient by mounting on human structure. The outcome gained through the performance analysis has been certainly validated through the comparative study under the findings of simulation and measurement.

Keywords: *SAR; On-body applications; Circular Ring; ISM (industrial, scientific, and medical).*

1. INTRODUCTION

Recent years have seen a rise in consumer interest in the quickly expanding field of wearable electronics. Applications for it are numerous and include sports, the military, space exploration, mobile medical monitoring, and healthcare. There is a lot of interest in the flexible and semi-flexible wearable technology for biological applications.

Most microwave antennas for bio-medical applications have recently been concentrated on monitoring physical parameters and promoting hyperthermia **[1]**. The temperature of cancer cells is measured using antennas positioned with internal and external characteristics within the feed network for an antenna developed with the structure of dipole or monopole representation created under the antenna by a low criterion development profile. To send physiological characteristics for study, the implanted antennas will function as sensors and communicate with external devices **[2], [3]**. Designing antennas of this type that function within tissues is difficult. Further, the requirements necessitating the matching of greater tissue reach, surface conductivity, matching for impedance value, dimensionality within the antenna, and bio-degradable density are the primary factors to be considered **[4], [5]**. Therefore, taking tissue shape and dielectric constants into account while simulating was necessary.

Various bands at sampled frequency exist for the implantation of medical requirements that are popular: the MIC bands, which span from 402-405 MHz **[6], [7]**. Utilizing an antenna structure with a stack base is substrate to the division of Rogers-3210 towards health equipment required in biotelemetry

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To examine the features of the reflection coefficient, the testing designed antenna can be majorly associated with the water capable of deionization and solutions within the cellulose of the material used. Such a configuration is applicable for monitoring or controlling glucose concentration. Furthermore, the antenna has been examined with the gel materialized in skin-mincing form for investigating functioning among the frequency ranging 402-405MHz and 2.4-2.48GHz. Medical applications can benefit from electrically tiny antennas **[8]**. To reduce the effective size of the antenna, different downsizing strategies described in the literature use greater substrate material directed to the current stream that was lengthened to patch the insertion created sorted in the patch and ground surface **[9-11]**. Besides serving the humans with the medium of loss concentration designed within the antenna created and placed there **[12]**. When the powering field is approximated with the temperature incremented to the intervention influenced within the therapeutic effects intervention to the determined characteristics, the temperature of human tissues near implants rises during high-frequency operations. To create efficient radiation qualities in implantable antennas, structuring with the meander for characterizing the antenna devised for the representation in nature to the domain of the featured structure developed **[13], [14]**. Upon the tracking of infected person's information through the data acquired from band created MICS designed antenna can be capable of transferring the information within the developed systems, that are insighted in the applications being fed to the properties of dielectric nature, the content of moisture, denier material, in addition to detecting the presence of electrically conductive objects. Particularly antennas are utilized therapeutically for numerous applications, including hyper thermic cancer treatment **[15]**, **[16]**, cardiac oblation**[17]**,**[18]**, angioplasty, and hypertension. For biomedical telemetry services, several antennas are designed for the approach into the fields of communication interface in wireless transferring that include coil, wired devices, inductive nature, and dielectric medium ferrite material associated further into structured domain**[19]** **[20], [21]**. A flaw in this device is that it generates rates for the lower range of tissues developed in the biocompatible to the placement required evaluated into FTDT analysis dipole or monopole inherent within the human bodies **[22]**. The research study suggests a small dual band antenna that is constructed and tested with the substrate of polyamide applied for the applications of onboard bodies. The suggested model remains iteratively generated and encased in a circular patch antenna. In this study, the body-centric antennas and SAR applications have developed in turn. The results from simulation and measurement are well correlated.

2. DESIGN METHODOLOGY OF ANTENNA

Antenna's basic design comprised the circular-based feeding of CPW with a monopole structure. Besides, the antenna substrate is flexible to the substrate to the polyamide into the medium dielectric for the approximated reach of 3.5 at loss tangent if 0.02. The antenna is 40*30*0.1 mm3 in size. Furthermore, the circular patch designed with the upper corner has truncated in the proper measuring of the slot developed by rectangular shaping in which division to the dimension of 2 x 22 mm^2measurement and has a radius of 12.5 mm.

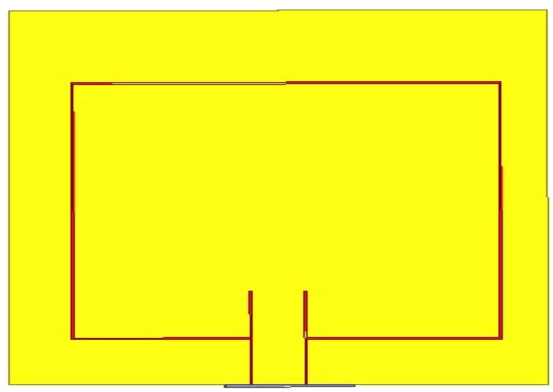

Fig. 1. Proposed Structure.

Figure 1 depicts the proposed structure of the antenna. The antenna is then added to the circular patch through a slotted part. A slot with a 2 mm line has been implanted within the centric region of the patch surface. A 50-ohm microstrip line with CPW feeding supplies the antenna. Contrary to the patch design line, two rectangular components make up the ground structure. Antenna with a g-sized gap between the feed with ground and line connected to the feed as dimensioned to be L_f x w_f.

3. RESULTS AND DISCUSSIONS

Certain bands at sampled frequency exist for the implantation of medical requirements that are popular: the MIC bands, which span from 402-405MHz. The frequency ranges of 2.45-2.48GHz, 868-868.6, 902.8-928MHz, and 433.1-434.8MHz are also recommended for medical ISM bands. The utilization of antenna structured with stack base is

substrate to the division of Rogers-3210 towards health equipment requiring biotelemetry.
Such an antenna with a dual-band configuration is applicable for monitoring or controlling glucose concentration. To examine the features of the reflection coefficient, the testing designed antenna can be majorly associated with the water, which is capable of deionization and solutions within the cellulose of the material used.

Furthermore, the antenna has been examined with the gel materialized in skin-mincing form for investigating functioning among the frequency ranging ISM 402-405MHz and 2.4-2.48GHz.To send physiological characteristics for study, the implanted antennas will function at 0.9 GHz impedance band mapped as sensors and communicate with external devices with a range of band attained to be 35%. The biocompatible tissues must be tolerated by these antennas, which must be tiny. It is difficult to design antennas of this type that function within tissues. Further, the requirements necessitating the matching of greater tissue reach in WLAN, LTE2300, ISM, surface conductivity, matching for impedance value, dimensionality within the antenna, and bio-degradable density are the primary factors to be taken into account.

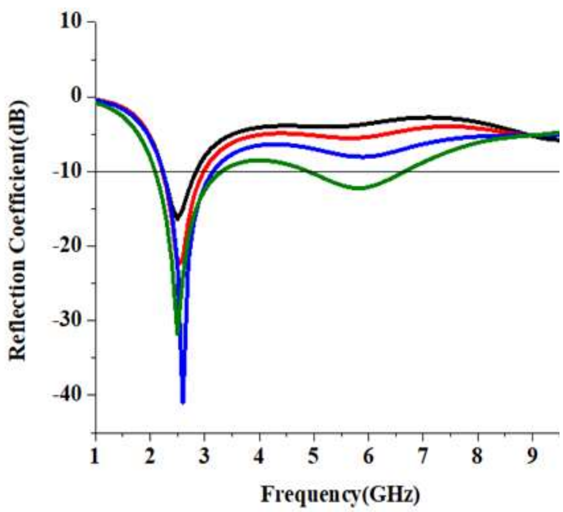

Fig. 2. Reflection Coefficient Of The Antenna Of Different Materials.

Figure 2 depicts the reflection coefficient of antennae of different materials. It is majorly associated with the water capable of deionization and solutions within the cellulose of the material used. Such an antenna with a dual band configuration is applicable for monitoring or controlling concentrated materials.

3.1. Obtained Radiation Efficiency with Peak Gain Value for the Proposed Antenna

It is possible to see the suggested antenna's maximum gain and radiation efficiency. With the outcome performed under the simulation process, the average gained value for the peak reach is around 1.9 dBi, 5.0 dBi under the bandwidth of 2.7 GHz, and 6.1 GHz, which has been investigated under the execution of 1st peak gain. When the antenna is used alone, the recorded peak gains are attained at the reach of 2.4 GHz and 6.0 GHz for gained values of 2.4 dBi, and 5.0 dBi. Similar to this, radiation efficiency for the designed antenna is seen in standalone mode, with a measured efficiency of 78% and 82% of radiation efficiency under simulation at 2.5 GHz. Moreover, the measured value of 85% radiation efficiency simulated for the antenna is attained at 6.1 GHz, under the note of 5.8 GHz bandwidth, with a difference from the measured one of 84%.

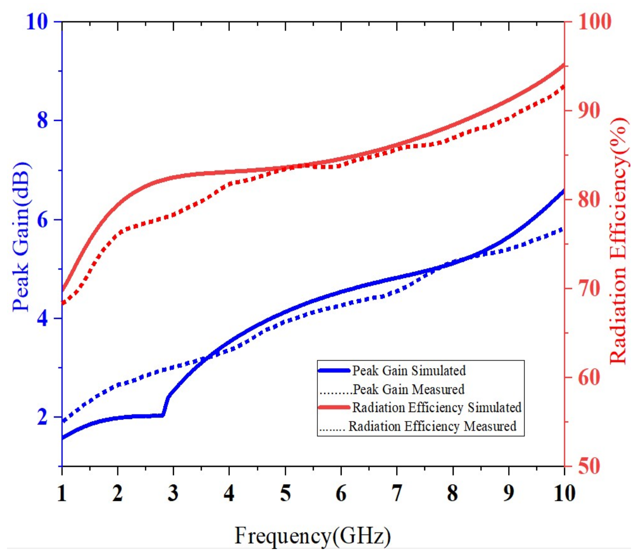

Fig. 3. Variations Among Peak Gains Of The Antenna Under Simulation And Measurements

Figure 3 depicts the variations among peak gains of the antenna under simulation and measurements. The anatomical human head model's highest radiation is observed to travel away from the human head model in this direction. On-body communication is crucial for minimizing radiation damage. It is possible to see the suggested antenna's maximum gain and radiation efficiency.

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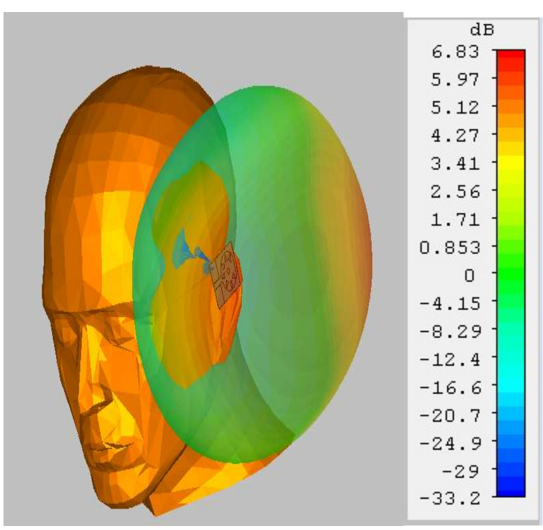
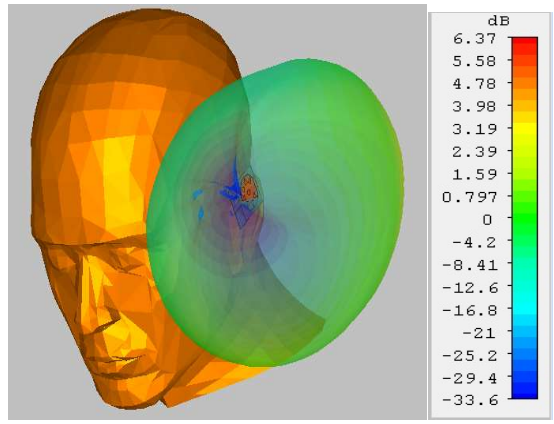
3. 2. Gain Characteristics of an Antenna Placed on the Human Head

Under the allocated positions of the antenna with the distinct human separate parts, the peak gain characteristics have been examined. With distinct, separate sampled bands, the gain patterns with the antenna design can be approached in the samples of 2.7 and 6.1 GHz bands under the antenna's 3D gain patterns are visible. Each pattern subjected to the radiation results in omnidirectional. The anatomical human head model's highest radiation is observed to travel away from the human head model in this direction. On-body communication is crucial for minimizing radiation damage. When an antenna is situated close to a human ear. Further, placement facilitated with the human's antenna overhead can result in patterns developed within the surface reach of 3D design. With the outcome reached, the antenna's gain is 8.21 dBi for bandwidth of 2.7 GHz, and 6.27 dBi for 6.1 GHz range frequency samples. The antenna has a 7.24 gain.

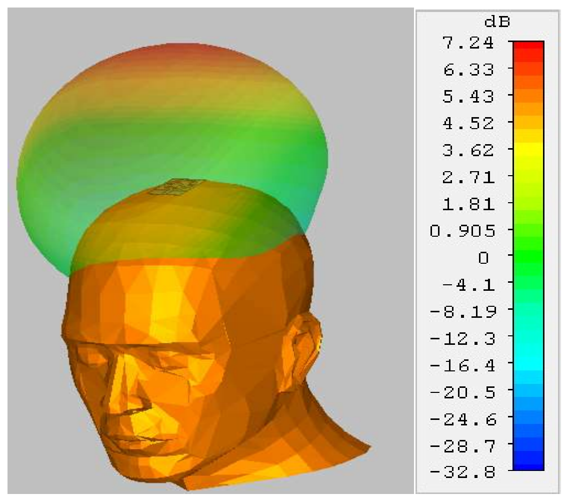
Figure 4 depicts the average gain value attained for the mounted antenna on the human ear with certain test cases of bandwidths. With separate sampled bands, the gain patterns with the antenna designed can be approached in the samples of 2.7 and 6.1 GHz bands under the antenna's 3D gain patterns are visible.



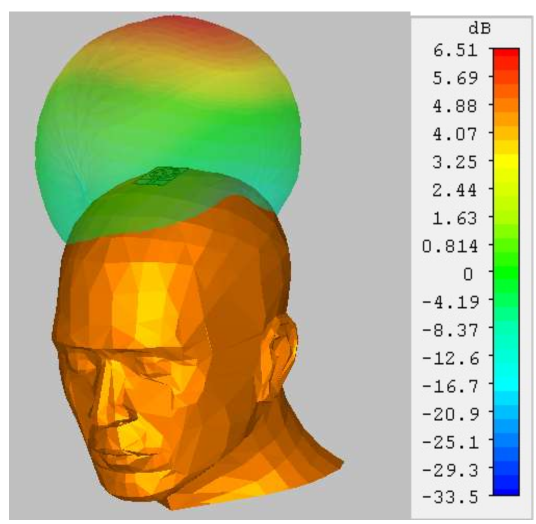
a) 2.7 GHz



b) 6.1 GHz



c) 2.7 GHz



d) 6.1 GHz

Fig. 4. Average Gain Value Attained For The Mounted Antenna On The Human Ear & Head With Certain Test Cases Of Bandwidths.

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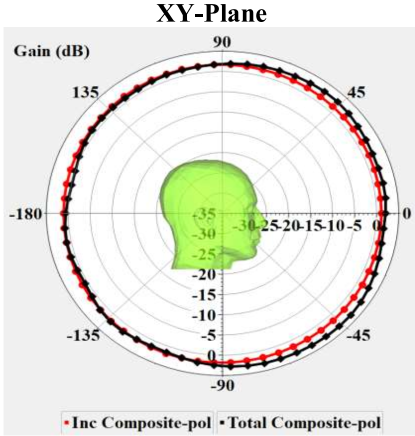
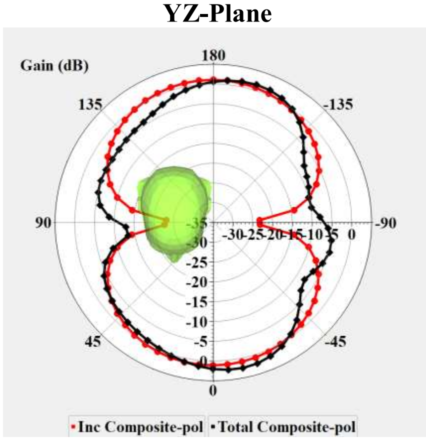
3. 3. Far-Field Radiation Characteristics on the Ear and Top of the Head

Ansys Savant simulation program utilized for the analysis of the far field effect on the designed antenna network, with the antenna allocated at 2 mm away with human part regional subjected to the model developed under CAD structure. Later, positioned in two separate locations on the human skull in a flat position. The XZ, YZ, and XY planes are three separate planes where far-field characteristics are indicated. At 2.5 GHz, the dipole-type radiation patterns that characterize the YZ-far pane's field radiation characteristics are dispersed along 1800 and 00. The dispersion of the patterned radiation taken into account under different coordinates of the plane that are scattered into the omnidirectional path for the planar surface of reflections in the plane of the XZ region remains scattered along +/- 900 angles and exhibits dipole-type radiation patterns. Similarly, the patterns associated with the effect of far fields can be attained in the range of 2.5 GHz with the bandwidth approach of 6.1 GHz.

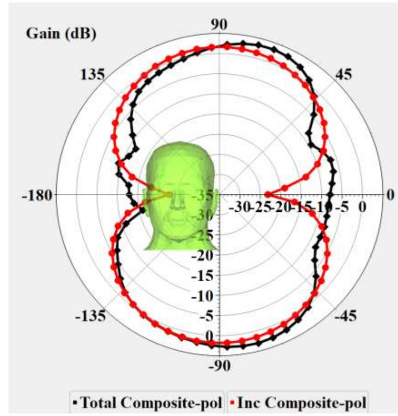
XY-Plane



YZ-Plane

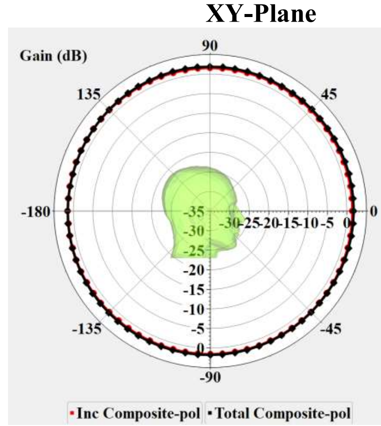


XZ-Plane

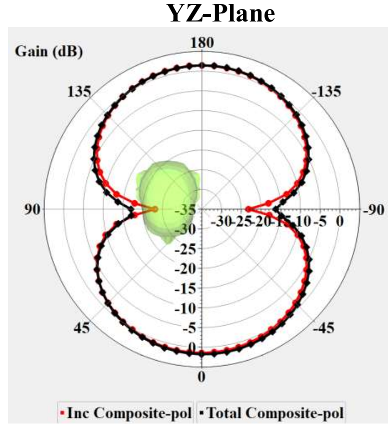


(a) 2.7 GHz

XY-Plane



YZ-Plane



XZ-Plane

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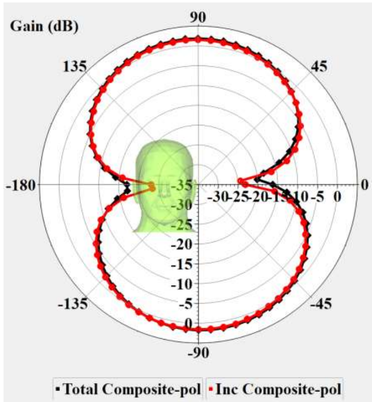
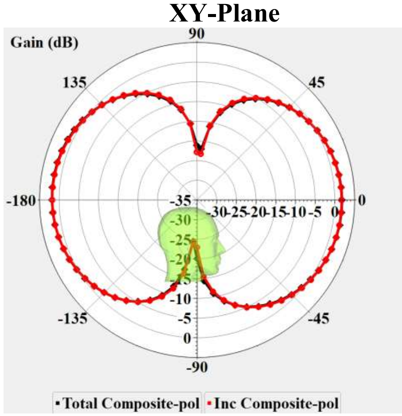


(b) 6.1GHz

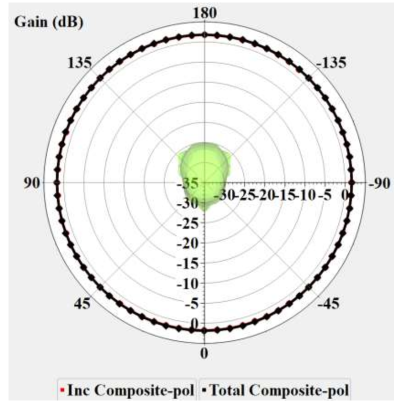
Fig. 5. Radiation Characteristics Of The Mounted Antenna On The Human Ear With The Effect Of Far Field.

Figure 5 depicts the radiation variations with its characteristic shown with the antenna mounted on the top of the human ear under the far field effects. The dipole-type far field under characteristics of certain radiation patterns with three coordinate planes of XY and XZ with the association of omnidirectional radiation patterns of the YZ plane is seen. In order to send physiological characteristics for study, the implanted antennas will function as sensors and communicate with external devices. It is difficult to design antennas of this type that function within tissues. The biocompatible tissues must be tolerated by these antennas, which must be tiny.

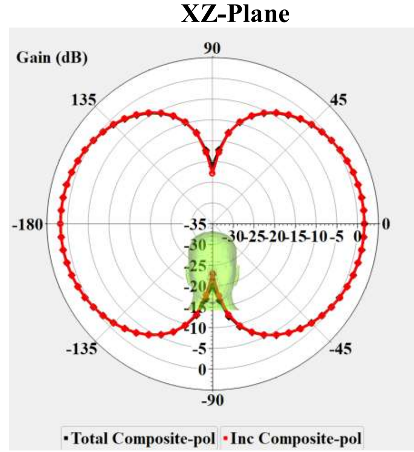
XY-Plane



YZ-Plane

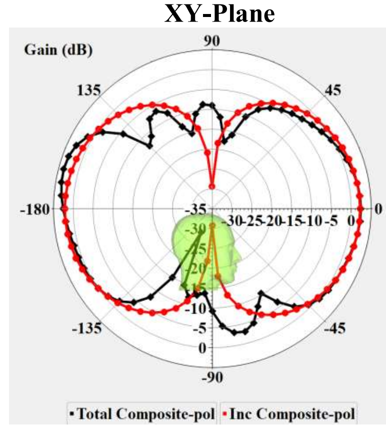


XZ-Plane



(a) 2.7 GHz

XY-Plane



YZ-Plane

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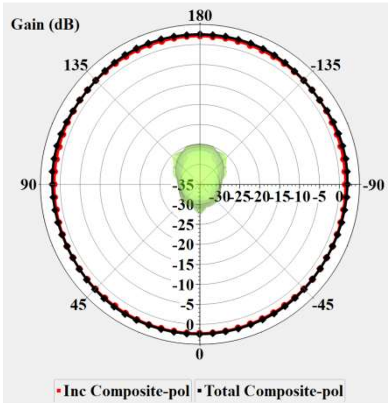
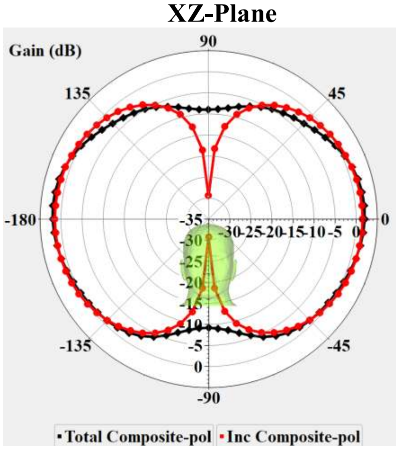


XZ-Plane



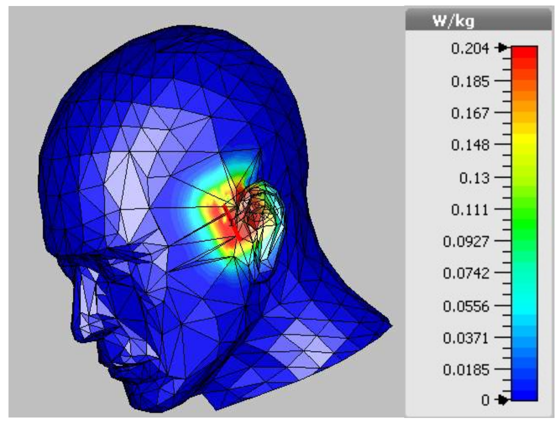
(b) 6.1 GHz

Fig. 6. Radiation Characteristics Of The Mounted Antenna On The Human Head With The Effect Of Far Field.

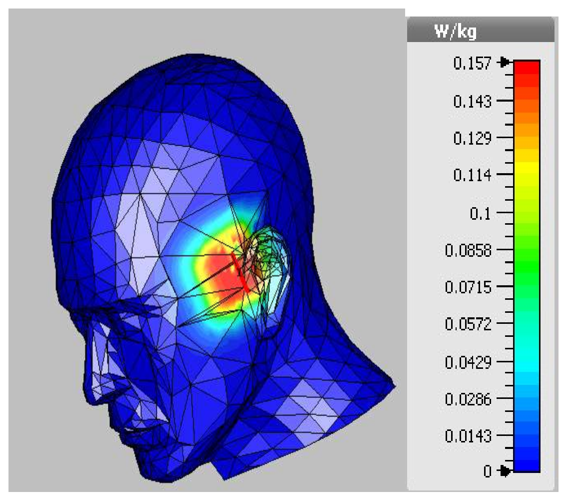
Figure 6 depicts the radiation variations with its characteristic shown with the antenna mounted on the top of the human head under the far field effects. The dipole-type far field under characteristics of certain radiation patterns with three coordinate planes of XY and XZ with the association of omnidirectional radiation patterns of the YZ plane is seen. In order to send physiological characteristics for study, the implanted antennas will function as sensors and communicate with external devices. It is difficult to design antennas of this type that function within tissues. The biocompatible tissues must be tolerated by these antennas, which must be tiny.

4. DESIGNED ANTENNA WITH ITS FEATURED CHARACTERISTICS OF SAR

Estimating the quantity of SAR within the system network is done to determine how much radiation will be released when an antenna is placed closer to the regional variation of humans. The design developed through the 3D model of analytical design can be observed by the studio based on the CST approach will later define the exact computation involved with the SAR determination. Thus, these SAR measurements were calculated subjected to the antenna allocation upon the mounted surface headed under two locations.



a) 2.7 GHz



b) 6.1 GHz

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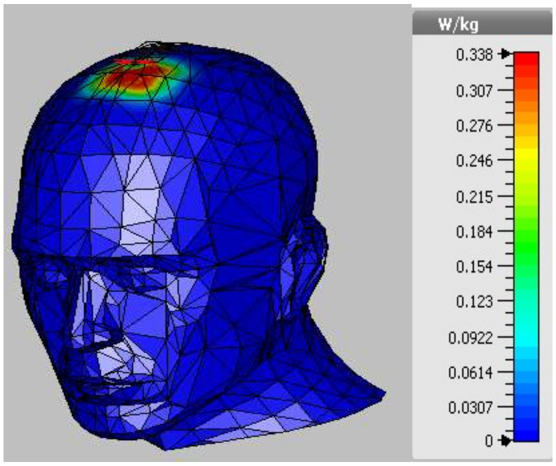
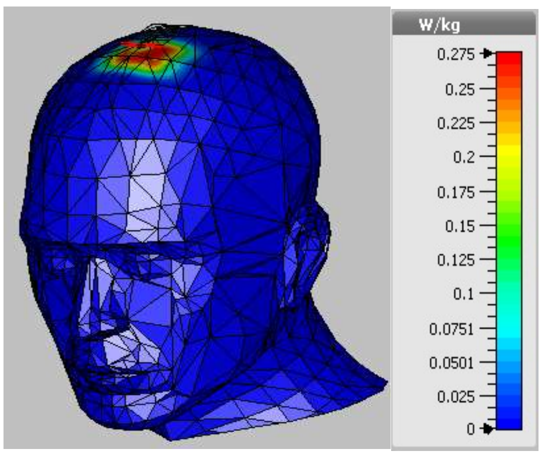


c) 2.7 GHz



d*) 6.1 GHz*

Fig. 7. A,B,C,D. Attained Band Ranges Within The Characteristics Of Sar On The Human Ear & Head Region At Certain Frequency Bands.

Certainly, the values of SAR can be computed based on the antenna designed within the region of the human ear at the probable band of 2.7 GHz and 6.1 GHz, with the average reach of 0.204 W/Kg, and 0.157 W/Kg in which the mounting took place at the region of the human head. Because more SAR values that are detrimental to the human head are created as antenna power increases, the benchmark gained at 100 MW with the reach in configuration employed to the designed antenna network. Due to huge count in mesh cells, it would take a very long time to evaluate the full human body, thus only the head phantom is taken into account. On average to the peak gain of 10 g, the mean could be attained at 0.338 W/Kg, in addition to the located reach for the regional heading towards the scenario of SAR characteristics. Over the range of 10 g, the mean reach could be around 1.6 W/Kg that configures to the facility acquired by FCC. **Figure 7** depicts the characteristics of the antenna with the reach of SAR attained upon the human ear within a certain band range. Nevertheless, communication between wrist band sensors uses the SAR that spreads throughout the featuring of the upper region of the human ear to the head top and can be radiated to the reach found within the system configuration. Since on-body radiated power levels are too low to reach far, the information to be transferred can be significantly done through the off-site state of the power that has been reflected through the permitted level of communication over wireless equipment about 15-25 meters. Thus, the antenna fit for the wearable applications can be provided to the sensors acquired within the on-body and off-site, often situated near one other.

Table 1. Comparative Analysis Of Proposed Approachwwith Existing Works.

S. No	Operating band	Dimensions (mm^3)	Substrate	Resonating Frequency	SAR values (W/Kg)
[3]	410-415 (MHz)	30.2 x 18.5 x 4	Silicon material	403(MHz)	0.31
[4]	412-415(MHz) 2.5-2.6(GHz)	24.2 x 23.6 x 3.1	Roger 3210	403(MHz) 2.45(GHz)	-
[7]	410-415(MHz) 902-928(MHz)	10 x 1.5	Rogers R03210	403(MHz) 910(MHz)	30.41
[17]	1.2-2.1(GHz) 4.5-7.8(GHz)	37 x 29 x 0.6	Rogers5880	3.1(GHz) 4.5(GHz)	0.875
[21]	2.5-9.7 (GHz)	29 x 19 x 0.7	Rogers 5880	3.6/7.2/10.5 (GHz)	1.23
Proposed Antenna	3.1-3.2 (GHz) 5.2-5.7 (GHz)	39 x 29 x 0.2	Polyimide	3.1 (GHz) 4.7 (GHz)	0.31 0.214

Table 1 illustrates the analysis of the performance of the antenna proposed in comparison to the current work based on its dimensions, resonant frequency range, and SAR values with the respective operating band frequency sampled at different substrates.

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- The proposed antenna has smaller SAR than [7,17,21]
- The proposed antenna is flexible in contrast to the previous antenna designs.
- The developed antenna operates at dual band compared to [3,21]
- Compared to existed antennas, the designed antenna has a peak gain of 7.25 dBi.

5. CONCLUSION

This article describes how to create an antenna of configuration with dual-band provided with the frequency ranging to ISM under the applications of wearable approach insight to the networking systems. The antenna developed attains a small size range, measuring 40*30*0.1 mm^3. Utilizing CST microwave studio, an on-body antenna examination is done. At the operational frequency, the antenna's 3D gain is seen. Incorporated to the characteristics of developed antenna which has been mounted over upper region acquired the maximum reach in gain value about 7.25 dBi. When the antenna was subjected to SAR analysis, it yielded 0.162 W/Kg within the minimal range under a human ear's location. Because the obtained SAR values are substantially less than 1.6 Watt/Kg, the antenna can be worn. Where in the bands associated under the band samples of WLAN, LTE 2300, ISM bands (2.46 GHz -2.49 GHz), and WiMAX are all covered by the antenna covering (5.725-5.825 GHz).

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