# Implementation of Novel Wearable Antenna Sensor at 800MHz for WBAN Applications

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***Abstract:-*** The technology of wireless wearable antenna sensors is driving the impressive expansion of wireless body area networks (WBAN) health and wellness monitoring applications. This is because body sensors are regarded as extremely sophisticated data collecting and information systems. Wearable, networked sensors that can be utilized on, inside, or outside of the body are a part of the human anatomy. The most recent international standard for WBAN is IEEE 802.15.6, which attempts to establish a standard for very dependable, short-range, low-power communication inside the human body. In light of this, a study was conducted to investigate and deploy novel, optimal wearable antenna sensors operating at 800 MHz. Additionally, their performance including path loss, channel modeling, power transmitted, power received, and other factors was examined in order to determine how well these sensors would work for IEEE 802.15.6 wireless body area networks applications. This work provides a thorough theoretical and practical investigation of the behavior of the suggested antenna sensor in relation to the human body and free space. The theoretical and experimental results correspond quite well, despite the intricacy of the human body's physiological behavior.

***Keywords***: WBAN, Wearable antenna sensor, Channel modelling, IEEE 802.15.6, Human Body.

## 1. Introduction

The proliferation of miniature sensors and the growing use of wireless networks have resulted in network applications that can be used on the human body to provide a wide range of services [1]. These days, the healthcare industry has seen a tremendous transformation because to the advancement of wireless wearable technologies [2]. A wireless body area network, or WBAN, is essentially a wireless sensor network, or WSN, put together with various nodes, actuators, and sensors, among other intelligent devices. Power consumption for intra- and inter-WBAN data transmission is high; therefore selecting the appropriate antenna for a given application is crucial [3]. In this context, the WBAN uses have known a large field of application domains, such as the medical domain [4], the military domain [5], sports [6], multimedia [7], etc.

Antenna sensor designs are crucial for cutting down on power consumption, decreasing channel loss, and boosting throughput. Wearable antenna sensor deployment, however, is hampered by a number of electromagnetic factors that can impair WBAN performance and wireless channel stability, including multipath, human body shadowing, fading and interference effects from signal attenuation, and energy absorption by bodily tissues[8] [9]. The study [10] states unequivocally that the human body is made up of naturally occurring absorbent layers. The attenuation of propagation signals along the human body is caused by these tissue layers acting as a low-loss dielectric medium.

It becomes necessary to reduce multiple electromagnetic variables in order to guarantee reliable body surface-to-body surface communication between the coordinator and the sensor nodes within the human body propagation environment. These include the human body's tissues avoiding radio signal diffraction, reflection, and absorption. Furthermore, characterization and analysis of the behavior of the wireless communication channel between devices installed on the human body become essential due to the complexity of the environment surrounding the human body. Characterizing propagation properties, signal attenuation, interference, and other body-centric limitations is the aim of this endeavor. Furthermore, the design and optimization of resource allocation plans, antenna designs, power control mechanisms, and communication protocols in Body Area Networks (BANs) depend heavily on precise channel modeling. Furthermore, this latter makes it possible for scientists and engineers to assess and enhance the functionality of wireless connections, guaranteeing dependable and effective communication between implanted or wearable technology and the outside network architecture.

A WBAN is regulated by IEEE Standard 802.15.6. This standard gives WBAN systems access to the physical (PHY) and media access control (MAC) levels. As a result, these layers are founded on precise simulations of wireless propagation channels and antenna layouts for various frequency ranges [9]. The IEEE 802.15.6 standard was created expressly to satisfy the requirements of various WBAN-dependent medical applications [1][2]. According to a study by Al Barazanchi et al. (2022) in [10], these applications include remote patient monitoring in healthcare institutions as well as the monitoring of elderly people in their homes. The primary objective of this standard is to enable short-range, energy-efficient wireless communication that can be used for applications on, inside, and around the human body.

Furthermore, there are three different categories for communications in BAN networks: There are three types of communication: in-body, on-body, and off-body. [11] [8]. In order to account for this, different channel models have been categorized based on the kind of body communication link—in-body, on-body, and off-body [12] [13].

Three possible scenarios for deployment are suggested by the WBAN standard: The human body has three types of nodes: (I) an implant node injected beneath the skin, which can be put in the deep tissues or just beneath the skin; (II) a surface node on the skin's surface; and (III) an external node, also referred to as the Gateway Node. The latter node is off-body and situated a few centimeters away from the skin [8]. In addition, four channel models have been established under the BAN standard: CM1 refers to the implant to implant; CM2 to the body surface model; CM3 to the body surface model; and CM4 to the external model [8] are the body surface to body surface models.

An essential and crucial component of wireless body area networks (WBANs) is the RF antenna sensor, whose design greatly influences factors such as radiation pattern, energy efficiency, directivity, transmission range, and radiation pattern. Over the past ten years, wearable antenna sensors have become increasingly important for on-body applications because of their capacity to identify microstructure deformations, human motions, and to monitor and oversee human health [14].

Standard industrial antenna sensors may offer precise data, but if integrated into body wear for sensing purposes, their large and stiff design restricts the user's movements. Thus, the creation of new antenna sensors that are compact in size, light in weight, low in power consumption, and flexible is crucial for WBAN applications. [15]

When creating WBAN-focused antenna sensors, one of the main study areas is choosing or creating appropriate materials for wearable antenna sensors. While a wide variety of antenna sensors have been produced for WBAN in the past, new and improved designs are constantly being created in response to market requests [16].

Since microstrip patch antennas have so many benefits, including low production costs, light weight, durability and dependability, and compact size, they are typically used in sensing applications. Due to the interaction of electromagnetic waves with dielectric characteristics, these function as sensors. [17][18]

In light of the aforementioned topic, new wearable microstrip antenna sensors optimized for 0.8 GHz were investigated, put into use, and their performance (including path loss, channel modeling, power transmitted, power received, etc.) was examined in order to use them for IEEE 802.15.6 international standard wireless body area networks applications.

## 2. Materials and Methods

This work proposes the use of HFSS-19 Software to operate a microstrip patch antenna at 0.8 GHz. Using a range of design flows and simulations, we have examined the effects of the human body on antenna performances. The suggested antenna is thought to be a very effective antenna for use in human applications. The Perfect Electrical Conductor (PEC) material is printed on a FR-4 dielectric substrate to create this wearable antenna. Because of its flexibility, this substrate material can be inserted into the body or fabric. Developing and positioning the antenna on the human body in a way that minimizes the impact of power absorption by the tissues is another difficult task. The substrate with a low dielectric constant of 4.4 and low dielectric height of 1.6mm was selected in order to lessen the influence that radiation waves would have on the human body and to have an efficient antenna in terms of radiation patterns.

The ground plane and feed line are composed of copper-annealed material, which is advantageous for on-bodies applications since it lessens the power that 800 MHz creeping waves absorb from human body tissues. We have changed the printed patch's width, length, and widths of the two inset gaps in order to maximize the suggested antenna's performance in terms of impedance adaptation between the patch and the feed line. Fig. 1 (a) and (b) depicts the suggested wearable antenna construction and its dimensional parameters.

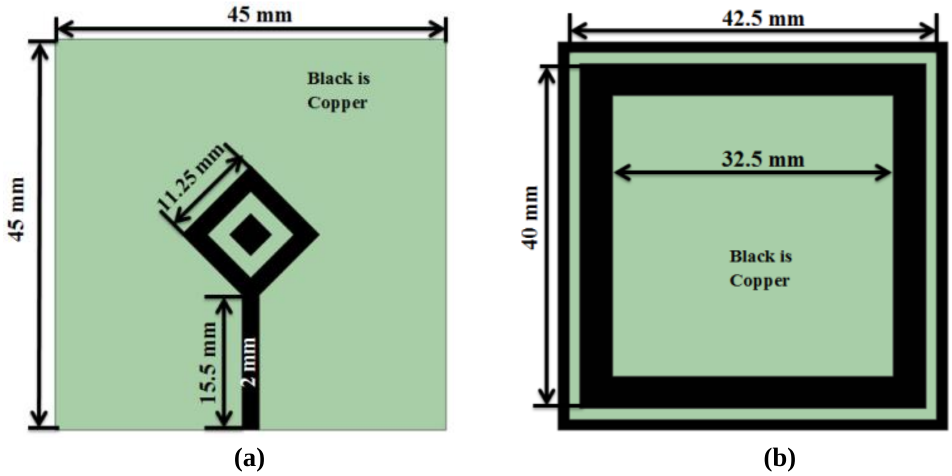


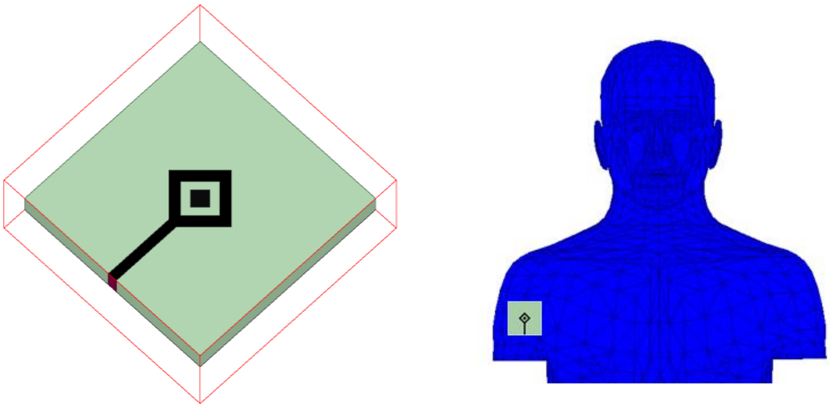

**Fig. 1.Proposed microstrip antenna sensor. (a). Top view with specifications (b). Bottom view with specifications**

The proposed antenna sensor is developed in the dimensions of 45 x 45 x 1.6 $mm^3$ with respect to length, width and the height of antenna. It was fabricated and tested to analyse its performance over simulated antenna. The performance analysis is illustrated in results and performance analysis section. The fabricated antenna images and measuring views of antenna under test (AUT) is given as Fig. 2.

**Fig. 2.Proposed microstrip antenna sensor Fabricated and Measured Views**

## 3. Results and Discussions.

With aim to use the proposed antenna sensor for IEEE 802.15.6 international standard wireless body area networks applications, implemented the new optimized wearable antenna sensor at 0.8 GHz as shown in Fig. 1. The radiation activities from proposed antenna sensor are observed by mounting the antenna sensor in free space (Fig. 3 (a)) and on human body (Fig. 3 (b)) i.e. the radiation behavior of the proposed antenna sensor on the free space and human body is theoretically and experimentally explored.



**(a)** **(b)**

**Fig. 3.(a). Mounting of antenna sensor in free space (b). Mounting of antenna sensor on human body**

Primarily, the performance analysis is done by measuring return losses (reflection characteristics) for simulated and fabricated wearable antenna sensors. In telecommunications measurements, the return loss term represents the loss of power, which have been returned or reflected from an antenna to a transmission line. It's a ratio between the incident power and the reflected power. The return losses extracted from simulation and measurements of the proposed antenna sensor by placing it in free space and on human body was plotted in Fig. 4. Hear, it's clearly observed that the antenna exhibit improved impedance matching, as indicated by a return loss measurement that falls below -10 dB line at 0.8 GHz in free space and in human body environments.

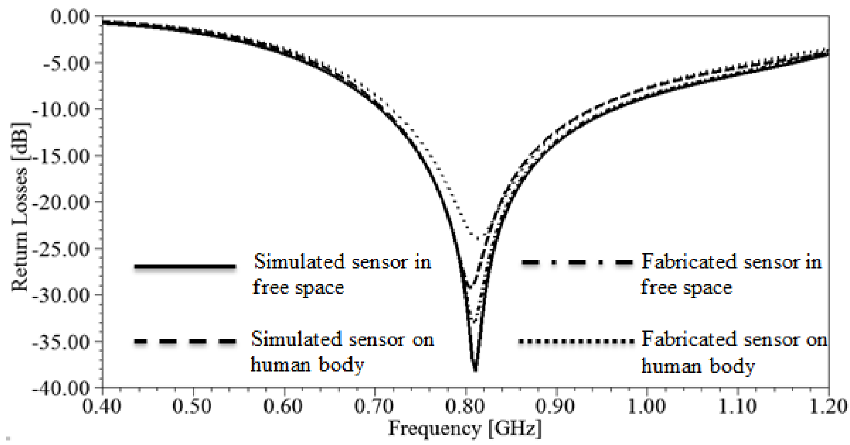



**Fig. 4.Reflection characteristics of simulated and fabricated antenna**

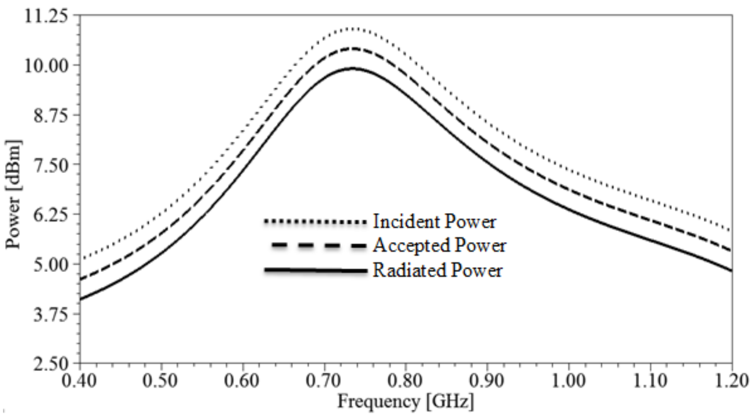
From extracted results of return losses, it was observed more return losses when the antenna placed on human body compared to the return losses when the antenna in free space, it may be due to the highest values of physiological parameters of the human body such as the conductivity of the muscle tissue and the power absorbed by each different tissue layers (Skin, fat, Muscle). The observed reflection characteristics (return losses) of the proposed antenna sensor from simulation and AUT are listed in TABLE I.

TABLE I. **Reflection characteristics of simulated and fabricated antenna**

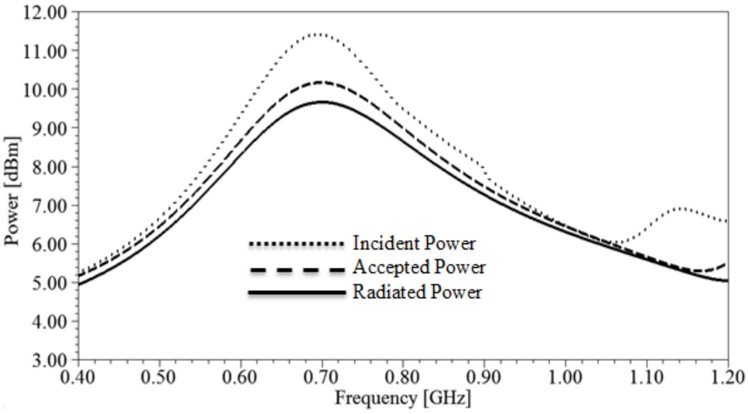
| **Simulated/ Fabricated** | **Free Space/ On Body** | **Operating Frequency band (GHz)** | **Peak Resonant Frequency (GHz)** | **Return Losses at PRF (dB)** |
|---|---|---|---|---|
| Simulated antenna | Free Space | 0.71 – 0.96 | 0.8 | -38.2527 |
| | On Body | 0.71-0.94 | 0.8 | -29.16 |
| Fabricated antenna | Free Space | 0.7-0.96 | 0.8 | -32.95 |
| | On Body | 0.72-0.94 | 0.8 | -23.95 |

Power is one of the important radiation characteristic in telecommunications measurements why because the transmission and reflection parameters are related to the power. The incident power on proposed antenna sensor, the accepted power and radiated power by the proposed antenna sensor are measured and the respected results are given as Fig. 5 (a) and (b).

From the above power measurements, it is observed that, as return losses states, the proposed antenna transmitting more than 90% of incident power. It is the good evidence to the achieved significant return losses. The Power measurements taken from simulated and fabricated antenna are listed in TABLE II.




**(a)**




(b)

**Fig. 5. Incident, accepted and radiated powers (a) Simulation of proposed antenna (b) measured from the AUT**

TABLE II. **Reflection characteristics and Power measurements of simulated and fabricated antenna**

| Simulated/ Fabricated | Frequency (GHz) | Incident Power (dBm) | Accepted Power (dBm) | Radiated Power (dBm) |
|---|---|---|---|---|
| Simulated antenna | 0.8 | 10.24 | 9.74 | 9.24 |
| Fabricated antenna | 0.8 | 9.48 | 8.98 | 8.63 |

The analysis of far field radiation is necessary and essential to study the impact of electromagnetic phenomena such as the influence of energy absorption on the power and gain of wearable antenna sensors in free space and especially in the presence of a human body. It is, therefore, necessary to understand the behavior of these devices in free space and in close proximity to the human body, as well as the influence of human body power absorption on the radiation performance of the wearable antenna. In the Fundamental mode of excitation, the proposed antenna radiates with significant gain towards the direction perpendicular to the patch. The proposed antenna has a gain of 2.1 dBi in the free space environment and 2.07 dBi in the human body environment at 0.8 GHz.

Fig. 6 (a) shows the 3D polar gain radiation pattern of proposed antenna at 2.4GHz when it placed on shoulder of on human body. However, according to the obtained results when the antenna is placed on human body, it was noticed a slight decrease of the antenna gain. Therefore, during transition, from free space to human body environment, the peak gain is reduced from 2.1dBi to 2.07 dBi, for proposed antenna sensor. It can be observed in Fig. 6 (b) also. Fig. 6 (b) is the plot of measured and simulated gain over all frequencies in sweep when the antenna in free space and on human body.

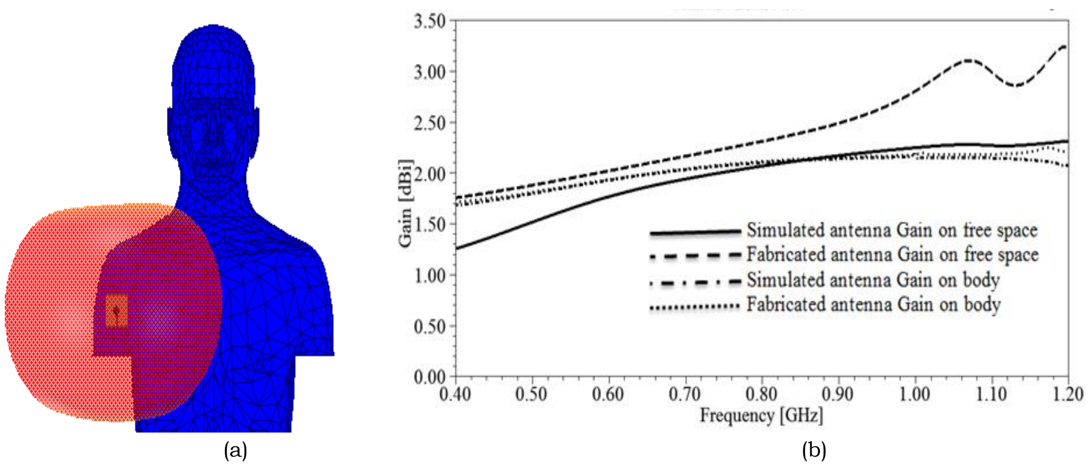



**Fig. 6. (a) 3D polar gain pattern on human body at 800MHz (b) Gain over the sweep when the antenna in free space and on human body.**

The slight decrease and attenuation in radiation patterns is may be due to the impacts of biological parameters of the human body such as the high conductivity of the muscle, skin and fat tissues. The Co and Cross polarizations of proposed antenna in free space and on human body environments were developed to know matching between the transmitting and receiving antennas.

The co and cross polarization results are shown in Fig. 7 along with principle plane (E & H plane) patterns. From Fig. 7 it is observed low cross polarization compared to co polarization and co polarized patterns have same level as principle plane patterns. So, as discussed [19][20], if observed low cross polarization compared to co polarization and co polarized patterns have same level as principle plane patterns, the characteristics of both transmitting antenna and receiving antenna are same. So, these observed far field gain radiation characteristics confirm that the proposed wearable designed antenna is suitable for free space and on-body medical applications.

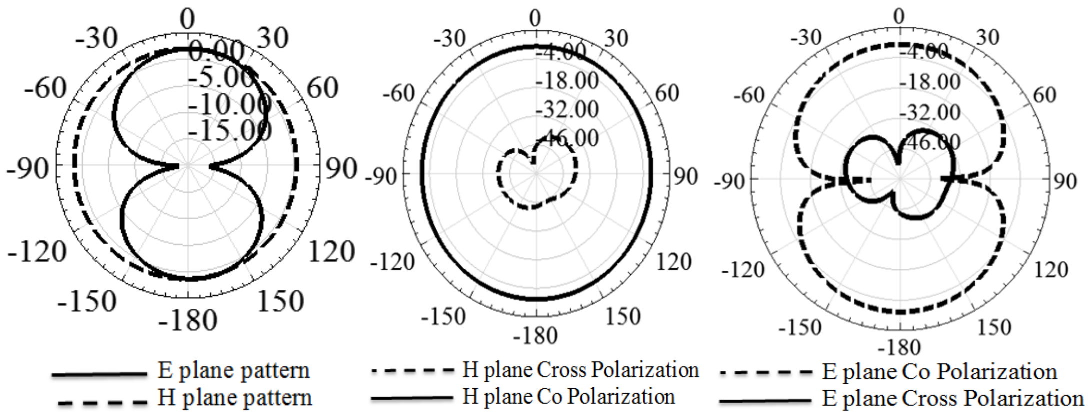
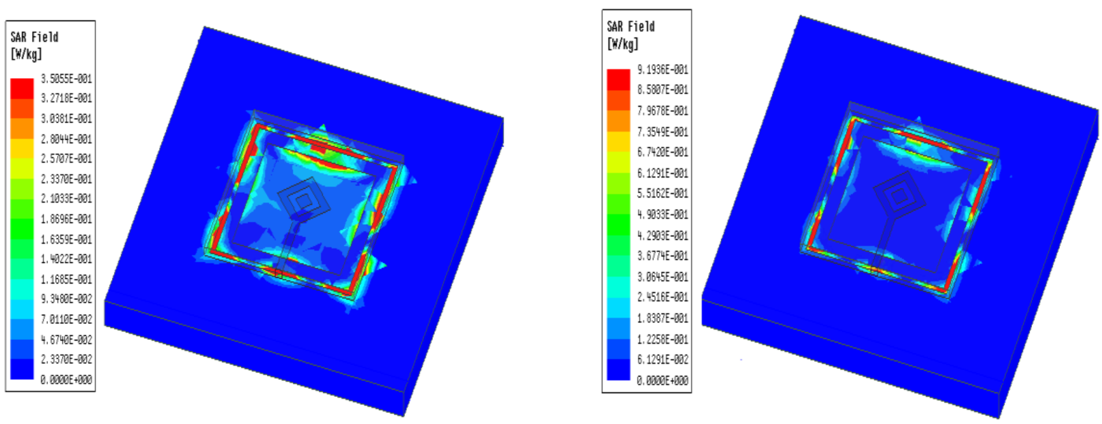



**Fig. 7. Co and Cross polarizations of proposed antenna at 0.8GHz along with principle plane patterns.**

Here presented a Specific Absorption Rate (SAR) analysis of proposed wearable antenna at 0.8 GHz for on-Body medical applications. A Human body is a complex propagation medium, it is highly conductive. As a result, human body tissue leads to additional effect to propagation waves such as diffraction, reflection, shadowing and power absorption. Considering the losses due to the human tissue frequency absorption and the complexity of this propagation environment, one of the most critical challenges in BAN is the design of efficient wearable antennas and the analyses of the Specific Absorption Rate (SAR) to protect the human body from radio frequencies and to ensure human body safety. The absorbed power per unit mass of human body is analysed by the SAR. Moreover, electromagnetic waves radiated by wearable antennas and penetrated in human body tissues can cause harmful and devastating effects of human body. The specific Absorption Rate (SAR) quantifies electromagnetic energy radiation absorbed by tissues and represents the amout of energy or power deposition per unit mass of biological tissue. The standard unit for SAR is watt per kilogram (W/kg).




**(a)** **(b)**

**Fig. 8.(a). SAR for 1g of human body tissue (b). SAR for 10g of human body tissue**

According to the study conducted in [2], the international community has standardized and regulated the SAR limitations. The maximum safety limit of SAR specified by the federal Communications Commission (FCC) is 1.6 W/kg for 1 g of tissue and 2 W/kg for each 10 g of tissue. In this work, it is calculated the SAR over 1g and

10g of human body tissue and shown in Fig. 8 (a) and (b), there it is observed 0.350 W/kg SAR over 1g and 0.919 W/kg over 10g of human body tissue. These SAR results make the proposed antennas suitable for Wireless Body Area Networks and for wearable applications. As per the initial report on channel modelling for wearable and implantable Wireless Body Area Networks (WBANs) specified in the IEEE 802.15.6 standard, the S21 parameter serves as the channel parameter employed to measure the path loss between the wearable antennas [2]. Therefore, in this work, it was studied the S21 (path losses) channel parameter for path loss modelling in on-body antenna distances and free space antenna distances. Here, the S21 parameter signifies the path loss between the transmitting antenna and receiving antenna separated with the distance of 'd' mm within the topology of the Body Area Network (BAN). The study of S21 is the electromagnetic interaction between the transmitting and receiving antenna elements controlled by varying distance 'd' between them. Actually the S21 and 'd', both are inversely proportional to each other.

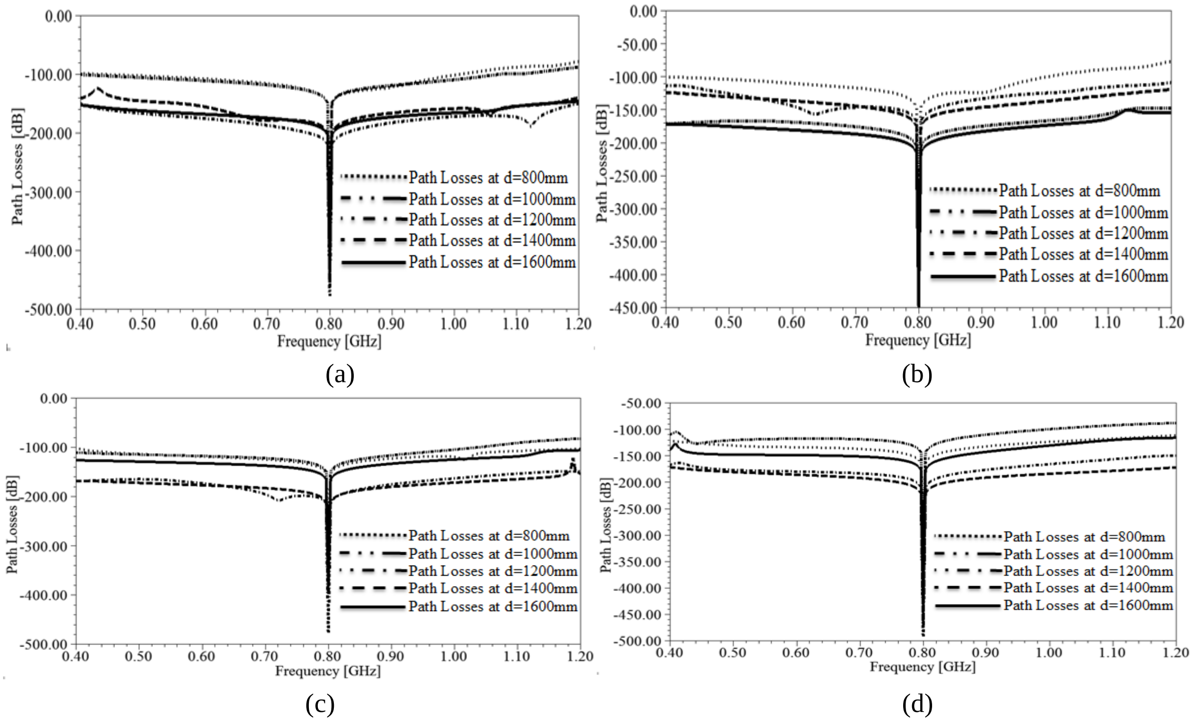



**Fig. 9. (a). Simulated Path loss characteristics from free space to free space over the sweep at different value of d (b). Measured Path loss characteristics from free space to free space over the sweep at different values of d (c) Simulated Path loss characteristics from human body to human body over the sweep at different values of d (d) Measured Path loss characteristics from human body to human body over the sweep at different values of d**

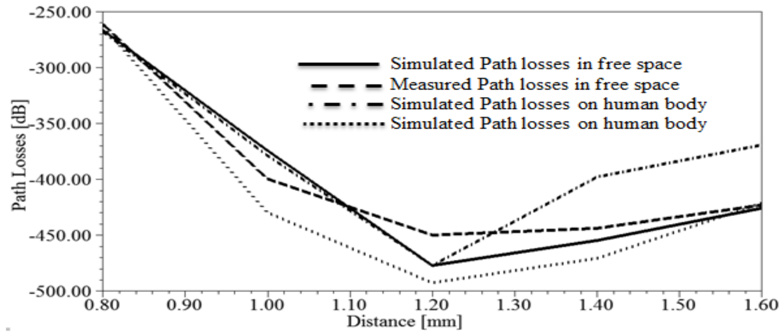



**Fig. 10. Path loss characteristics over distance between transmitting and receiving antenna at 0.8GHz**

In the proposed work, Fig. 9 (a) and (b) (Path loss characteristics from free space to free space over the sweep) and Fig. 9 (c) and (d) (Path loss characteristics from human body to human body over the sweep) presents the simulated and measured scattering S21 parameter between transmitting and receiving proposed antennas at various values of 'd' over the sweep. As per the survey, the researchers suggested less than of -15dB path losses. The studies from Fig. 9 (a), (b), (c) and (d) justified the distinction path losses in proposed work. From this study of path losses over frequencies in sweep, it was computed path losses over different distances'd' at 0.8 GHz and shown in Fig. 10. From Fig. 10, it was observed the shrinkage of path losses as distance increasing to certain value (1200 mm) after that observed heightening the path losses with the increasing of distance with same amount from that certain distance value. From this study of path losses over the distance, it is summarized that the 1200 mm distance is suggestible for better electromagnetic interaction between transmitting and receiving antenna on both free space and human body.

## 4. Conclusion

The proposed work presented path loss modelling between wearable antenna sensors at 800MHz in both free space and human body environments. The proposed model can be applied for channel modelling in the WBAN field. Also, it is proposed a design flow and performance analysis of the wearable antenna in free space and on human body model. The performance of the proposed antenna in terms of return loss, and gain in both environments has been studied. Moreover, a SAR analysis has been performed to ensure human body safety. According to the obtained simulation results, we have examined the channel attenuation between the transmitting and receiving antenna placed on different positions using S21 parameter.

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