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# Design of Textile Wearable Antenna for WBAN Applications

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*Abstract:* For treating difficult medical diseases, biomedical gadgets are receiving a lot of attention. In this research, a wearable Microstrip patch antenna for biomedical purposes that operates at a 2.45 GHz frequency range in the ISM Band is shown. A unique patch structure has been developed to excite the antenna in this design, which uses an edge feed. To maximise the antenna's flexibility, it will be embedded into a cotton cloth instead of a copper plate. The antenna is suited to be put in direct contact with the human body as a result. The antenna's design met a number of criteria, including biocompatibility, fulfilment of the Specific Absorption Rate (SAR), efficient radiation characteristics, and shrinking of the antenna's size. As a result, this antenna may be used for both on-body and off-body communications. The suggested antenna may be employed in WBAN applications, according on the findings of measuring the usual antenna characteristics. Fabrication, measurement, and testing of the prototype are required.

**Keywords— Antenna, WBAN, microstrip patch antenna, SAR, on-body communication, off-body communication, textile antenna, wearable antenna**

## 1. Introduction

Biomedical engineering is one of the most rapidly expanding technological areas, a sector with recent successes and far more loftier ambitions. In this setting, WBAN supporting healthcare applications may provide significant improvements to patient healthcare, including monitoring of treatments and/or diagnostics. In a short period of time, WBAN technology has made its initial inroads into patient monitoring and medical rehabilitation [1]–[2].

The most important factor in a WBAN with a few metre ranges is the design of a particular radiator. For data transfer, attributes including radiation effectiveness, bandwidth, coupling with lossy biological tissues, and use of available space are crucial. Using WBAN, medical professionals must monitor several patients at once while the patients are comfortably observed at home going about their everyday lives.

In order to provide care and ensure human safety, biomedical antennas are used to wirelessly convey diagnostic data from an electronic device implanted in or applied to the human body. In order to create a bio-communication system between medical equipment and outside instruments for short range biotelemetry applications, antennas may either be implanted into human bodies or simply put over the torso (skin-fat-muscle). Economic considerations are important in addition to the obvious advantages that body implanted technologies provide the healthcare system. Systems for remote monitoring make it easier to diagnose illnesses and benefit the in-home hospital by shortening the length of stay. The goal is to create a linear impedance line using the edge feeding method and use it for biological purposes. To achieve flexibility, the textile material is employed as a foundational component. The antenna is simulated using Ansys EM Solver. It is made and tested [1] through [5].

With SRR serving as the ground and transmission lines placed in an array to form a patch, this method suggests designing and developing a small antenna that functions at the 2.45 GHz frequency. The flexible foundation material is made of textiles, which may come into touch with the human body. The antenna has been tested to have an efficiency of 77.5 percent with gains of 5 dB in steady and 3.1 dB in running state. This enables the antenna to be usable for both on-body and off-body communications. [6]-[8].

## 2. Antenna Design and Structure

### 2.1 Selecting a Template

The design specification is made up of the many requirements needed to create the suggested antenna. The antenna is positioned directly on the surface of the human skin without damaging the human tissues, and it is made to be suited for both in-body and off-body communication [10]–[13].

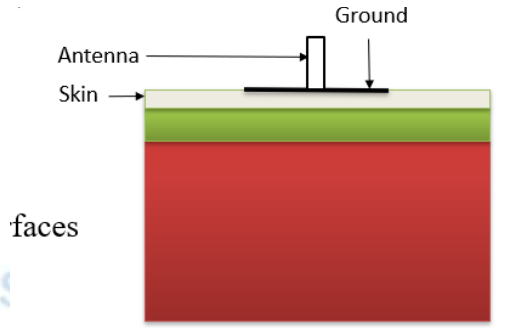
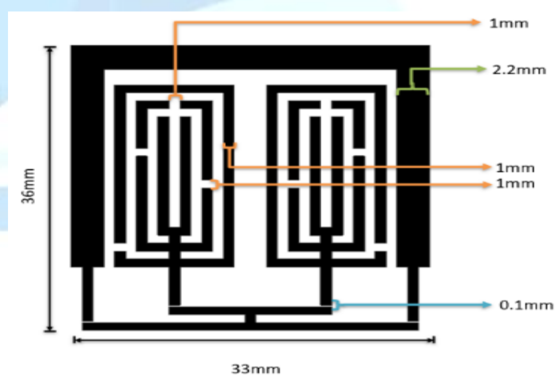



**Fig. 1.** *The wearable antenna*

Ansys High Frequency Structure Simulator (HFSS) software is used to model the layout. When textile materials are used in conjunction with a focused design approach, body components are flexible, light, and function well. Longer communication distances, reduced power consumption, and greater bit rates are made possible for the system's advantage. The most well-known resonant varieties of meta-structure are Complementary Split Ring Resonators (CSRR). the feed location being correctly adjusted in relation to the split gap of the CSRR[15].

Furthermore, depending on the relative alignment between the two CSRR-based patches, dual or triple band operation with different polarisation will also be conceivable. The dimensions listed below were used to create the edge-fed metamaterial surface microstrip patch antenna. Ansys High Frequency Structure Simulator (HFSS) software is used to model the layout. Figure 2 below displays the metamaterial surface antenna schematic..



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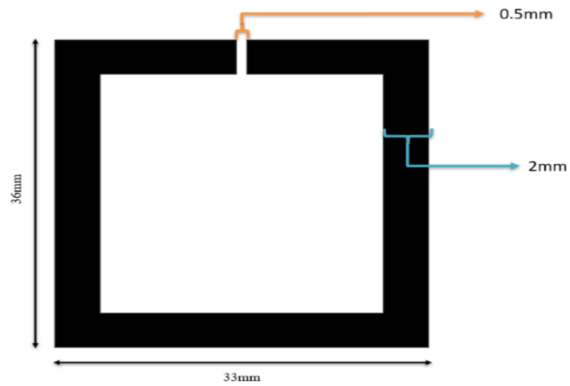


**Fig. 2.** *(a) Schematic of metamaterial surface antenna. (b) Ground structure – CSRR*

The substrate and patch have thicknesses of 2.8 mm and 0.2 mm, respectively. This fictitious patch will be created on cotton fabric, which has a relative permittivity of 2.1. The suggested antenna will be 3.3 mm in length and breadth overall. This displays a small version of the intended antenna.

**Table 1.** *Dimensions of Substrate and Patch*

| | ***Length*** | ***Width*** | ***hickness*** |
|---|---|---|---|
| ***Substrate*** | 36 mm | 33 mm | 2.8 mm |
| ***Patch*** | 36 mm | 33 mm | 0.2 mm |

A. Abbreviations and Acronyms

Even if they have previously been defined in the abstract, define acronyms and abbreviations the first time they are used in the text. There is no need that acronyms like IEEE, SI, ac, and dc be specified. Avoid using spaces in abbreviations that include periods; instead, use "C.N.R.S." rather than "C. N. R. S." Unless it is absolutely necessary (like "IEEE" in the title of this article), avoid abbreviations in the title.

The microstrip patch antenna used in simulation and outcome is for WBAN applications and operates at 2.45 GHz. Each criteria for the design is separately demonstrated, and the results are provided.

A. RETURN LOSSES OF THE WEARABLE DRA

[23]-[24] Return loss in communications refers to the loss of power in the signal that is reflected or returned by a break in an optical fibre or transmission line. This break may be caused by a mismatch with the ending load or a device that has been added to the line. Typically, it is presented as a decibel ratio (dB). The return loss of the intended antenna is shown in the image below.

Return loss, RL = -20 log10 |1/T|

Return loss, RL = -26.873

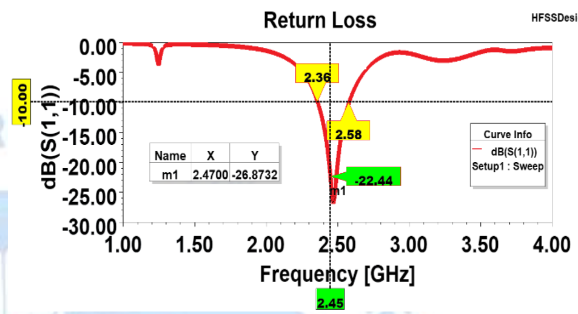


**Fig. 3.** *Return loss of the designed antenna.*

B. REFLECTION CO-EFFICIENT

The number of electromagnetic waves that are reflected as a result of an impedance discontinuity or mismatch in a transmission route is indicated by the reflection coefficient, an electrical quantity. Below is a description of the reflection coefficient's formula.

$$\Gamma = 10^{\frac{-RL}{20}}$$

Where $\Gamma$ = Reflection Coefficient and

RL = Return Loss

Reflection co-efficient = 22.0627

*C. VSWR OF THE WEARABLE ANTENNA*

The frequency range over which a microstrip patch antenna is within predetermined bounds matched with the feed line is known as its VSWR or impedance bandwidth. The graph of the planned antenna's VSWR is shown in figure 4.

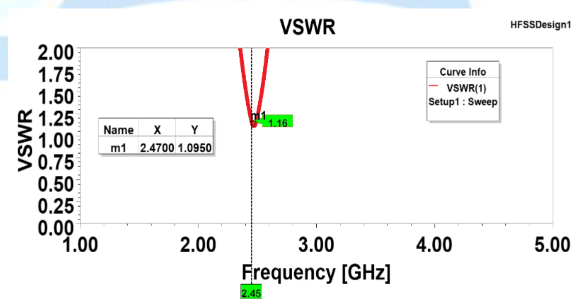


**Fig. 4.** *VSWR of the designed antenna.*

$$\Gamma = \frac{VSWR-1}{VSWR+1}$$

Where $\Gamma$ = Reflection Coefficient

$$VSWR = 1.0950 \approx 1$$

D. IMPEDANCE

For antenna the reactance will be zero, so, jX = 0. Therefore, Z=R=1. This shows that the impedance is perfectly gained thus the antenna will not cause any irritation to human and does not create any back radiation and provide safety for human cells.

$$\text{Impedance, } Z = R \pm jX$$

$$\text{Impedance} = 0.91 \approx 1$$

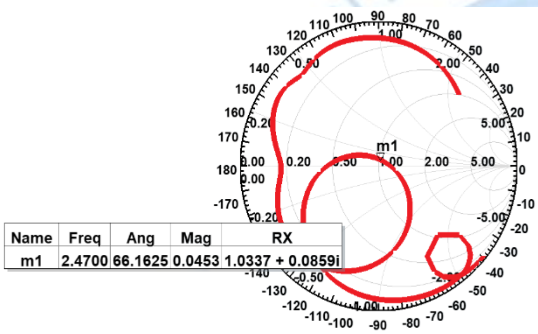


**Fig. 5.** *Impedance plot*

E. RADIATION EFFICIENCY

By applying some power to the antenna feed pads and measuring the intensity of the emitted electromagnetic field in the surrounding area, the antenna efficiency is determined in an anechoic chamber. The radiation efficiency of the suggested microstrip patch antenna is shown in figure 6 below.

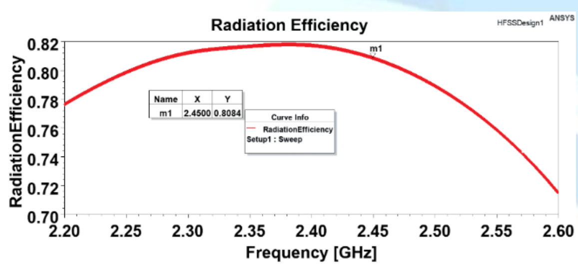


**Fig. 6.** *Radiation Efficiency*

F. GAIN AND DIRECTIVITY

The ability of an antenna to emit more or less in any direction as compared to a theoretical antenna is known as antenna gain. An antenna would radiate evenly in all directions if it could be constructed as a perfect spherical. Antenna gain is a measurement of how effectively an antenna can direct the power that a transmitter sends to it in the direction of a target [9]–[10].

Directivity of an antenna is defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The designed antenna will give the directivity of 5 in stable position and the provide the maximized directivity of 4.

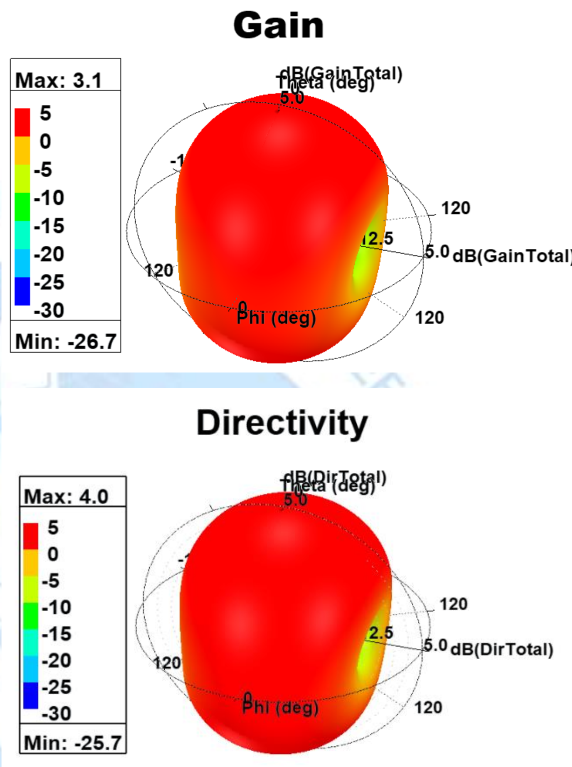


**Fig. 7.** *(a) Gain (b) Directivity of the designed antenna*

G. ANTENNA EFFICIENCY

Gain and efficiency are related by the formula G = e x D, where D stands for directivity and E for efficiency. The efficiency of the developed antenna will be 77.5 percent, which is the safe efficiency for the textile ISM band antenna, after being computed regarding gain and directivity.

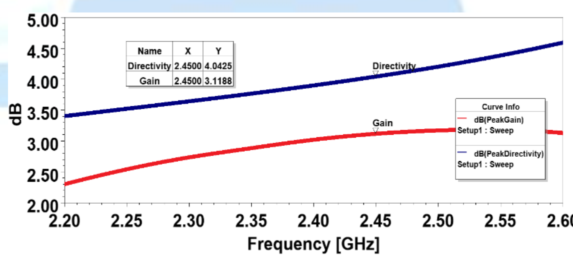


**Fig. 8.** *Antenna Efficiency of the designed antenna.*

H. POLARIZATION

A rough definition of an antenna's polarisation is the direction in which electromagnetic fields it generates when energy emanates from it. The direction that

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energy travels away from or is received by an antenna is determined by these directional fields. [11]-[15].

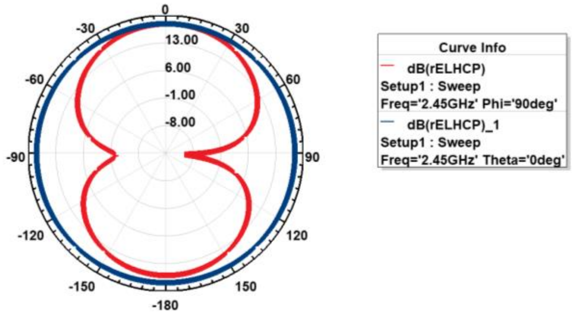


**Fig. 9.** Circular polarization in forward direction.

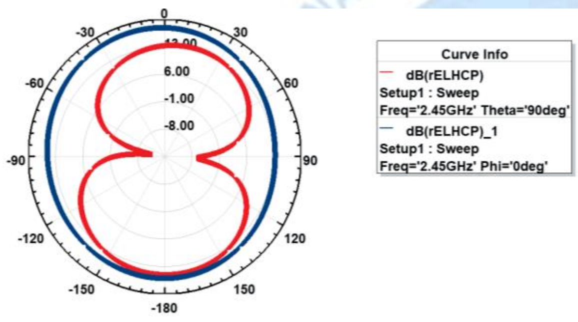


**Fig. 10.** *Circular polarization in backward direction*.

SPECIFIC ABSORPTION RATE

One of the most crucial characteristics of a biomedical antenna system is Specific Absorption Rate (SAR). It gives a measurement of how quickly energy is absorbed by the body after exposure to an RF electromagnetic field. The antennas are essential for modern bio-telemetry applications, notwithstanding the risks of injuring human tissues owing to power absorption and heating. Therefore, the problem is to successfully preserve the SAR within the IEEEC9S.1-1999 prescribed value (1.6 W/Kg for 1 g tissue model) while reducing it without compromising the typical antenna characteristics [12]– [13].

The electric field inside the tissue may be used to compute SAR for electromagnetic radiation as follows:

$$\mathrm{SAR} = \frac{1}{V}\int_{\text{sample}} \frac{\sigma(\mathbf{r})\left|\mathbf{E}(\mathbf{r})\right|^2}{\rho(\mathbf{r})} d\mathbf{r}$$

SAR measures exposure to fields between 100 kHz and 10 GHz (known as radio waves). It is commonly used to measure power absorbed from mobile phones and during MRI scans. The value will depend heavily on the geometry of the part of the body that is exposed to the RF energy, and on the exact location and geometry of the RF source. Thus, tests must be made with each specific source, such as a mobile phone model, and at the intended position of use. The SAR value obtained for the proposed antenna is 0.2 Watt/kg which is below 1.6 W/Kg as per the IEEEC9S.1-1999 specified value. Thus, the designed antenna is suitable for the WBAN applications without affect the tissues of the human body[16]-[22].

## 3. CONCLUSION

One of the key components in the design of wearable and portable electronics are wearable antennas. They are appropriate for outdated wireless networking and sensor applications because of their conformal properties, adaptability, affordability, and light weight. The tiny strip antenna that is employed is a good contender for wearable applications since fabric substrate materials may be used to construct it. The dielectric constant of textiles is typically between 1 and 2. So it can increase antenna bandwidth while reducing surface wave losses. To lessen frequency-related harm to human cells, thin transmission lines are utilised as the substrate. Under the frequency of 2.45GHz, the antenna shown has obtained 3.1 dB gain and 0.2 Watt/kg of SAR. The developed antenna also satisfied other antenna criteria with a 77.5 percent efficiency, making it appropriate for WBAN applications.

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