DESIGN AND DEVELOPMENT OF WEARABLE ANTENNA FOR PROACTIVE TUMOR DETECTION

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ABSTRACT

In recent years, wearable electronics have gained opportunities and the past decade has become evidence of this growth in Wireless Body Area Network (WBAN). They fulfill the requirements of personalizing healthcare, communication, patient monitoring, tracking, and rescue operations. The major challenge for the WBAN is to handle the coupling of the radiator with the human body. To increase the performance of a microstrip patch antenna, it has been blended and truncated on the diagonal sides to make up the suggested antenna design. Flexible electronics have paved the way for Wireless Body Area Networks (WBAN). This allows for optimal performance. The square patch, measuring 50 × 50 mm, resonates at the 2.4 GHz ISM band, which is frequently utilized in wireless communication applications. The FR-4 substrate, which has a relative permittivity of 4.3, was selected for the antenna. It is a lossy material with a thickness of 1.6 mm and dimensions that match those of the ground plane (50 x 50 mm). Perfect Electric Conductor (PEC) is the material used for the patch. Its dimensions are 30 × 30 mm, or half the wavelength at the resonance frequency To further improve performance, a slot is added to the patch's center. A secondary ground plane measuring 90 x 90 mm and 2 mm thick is placed beneath the primary ground plane in addition to the main ground plane to improve radiation efficiency and antenna stability. In order to maximize signal strength and coverage, the coaxial feed in the design is carefully calibrated to improve gain. The design seeks to improve impedance matching, radiation pattern, and overall antenna performance by truncating and blending the square patch antenna in addition to adding a slot and an extra ground plane. In order to maximize efficiency and reliability and satisfy the criteria of the 2.4 GHz ISM band, much consideration is given to the choice of materials and dimensions. The proposed antenna is designed and simulated using CST Microwave Studio software. The proposed antenna is an efficient antenna with realized gain of 2.88dBi, low VSWR and wide bandwidth.

KEYWORDS: Microstrip patch antenna, 2.4Ghz ISM band, Antenna performance, Gain, reflection coefficient.

INTRODUCTION:

Wearable technology is the integration of computer and electronic technologies into everyday objects like clothes. Accessories that can be worn include fabrics, jewelry, watches, headgear, and eyeglasses. These devices include features similar to those of smartphones and PCs, in addition to providing tracking, sensing, and scanning capabilities[1]. This is a big development for ubiquitous computing since it makes information accessible from anywhere[2,3]. Among textile structures features, built-in antennas have shown to be an essential component of wearable technology, enabling wireless communication through clothing[4]. Among other things, wearables can be used as monitoring systems for assisted living and life care.Wearable textile systems are created when these monitoring devices are paired with textile clothing[5,6]. For a long time, antennas have been used in many different medical applications, including as medical implants, hyperthermia treatments, microwave imaging, and remote health monitoring. An antenna is, generally speaking, a device that can both receive and send electromagnetic waves [6,7]. Micro-strip patch antennas are frequently employed in communication systems and search engines to establish the necessary communication links for biomedical equipment.Micro-strip antennas are attractive because they are lightweight, low profile, simple to operate, and inexpensive to produce. The advantages of a small, inexpensive feed network are realized. Micro-strip antennas have been used extensively in books and publications over the past ten years[8,9]. Therapeutics and diagnostics are the two main uses for medical antennas. The antenna is either directly in contact with the skin or incorporated within the human body in therapeutic circumstances[10]. However, in diagnostic applications, the antenna is worn as a wearable device or placed completely outside the body, either in direct contact[11,12]. Wearable antenna concepts for biomedical applications are shown in Figure 1.1.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 05 | May 2024 www.irjet.net p-ISSN: 2395-0072

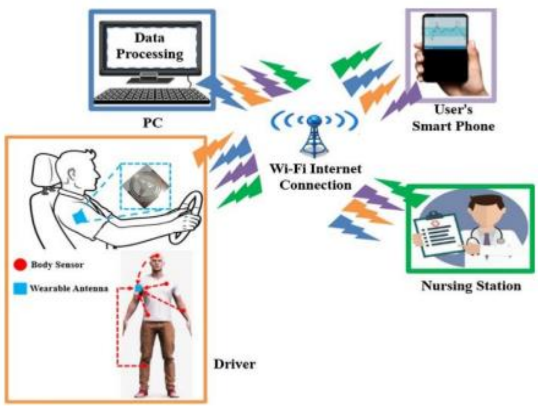

Fig1.1 Wearable antenna for biomedical applications[12].

For wearable applications, textile patch antennas are the most widely used type of antenna topology among others. These antennas' flat configuration, straightforward design, versatility, lightweight, and effortless integration into any outfit make them perfect for wearable applications[4,13]. An insulating fabric substrate is incorporated into the wearable patch antenna (WPA) design and is positioned between the conductive patch and the conductive ground plane. Furthermore, the addition of a conductive ground plane layer reduces the possibility of skin damage from the antenna's back radiation[13,14]. Researchers face a number of difficulties in the creation and optimisation of WPA, such as concerns about power consumption, frequency band coverage, adaptability, compact size, and interaction with textiles.

To overcome these obstacles, it will take coordinated efforts from various research fields to develop WPA that are not only dependable and efficient but also easy to use[15]. These antennas consist of a substrate composed of a different textile material and a textile conducting element[16]. They are inexpensive, lightweight, flexible, easy to produce, and straightforward to include into a garment. In order to reduce the need for labor and resources, textile antennas that can perform a variety of tasks, including monitoring, alerting, and requesting assistance if a healthcare emergency arises, are currently being developed[17]. In our work we are simulating an antenna to detect cancer.We are designing a wearable patch antenna to detect cancer .

PROPOSED DESIGN

A square patch antenna that has been blended and truncated on the diagonal sides makes up the suggested antenna design. This allows for optimal performance. The square patch, measuring 50 × 50 mm, resonates at the 2.4 GHz ISM band, which is frequently utilized in wireless communication applications. The FR-4 substrate, which has a relative permittivity of 4.3, was selected for the antenna. It is a lossy material with a thickness of 1.6 mm and dimensions that match those of the ground plane (50 x 50 mm). Perfect Electric Conductor (PEC) is the material used for the patch. Its dimensions are 30 × 30 mm, or half the wavelength at the resonance frequency.

To further improve performance, a slot is added to the patch's center.A secondary ground plane measuring 90 x 90 mm and 2 mm thick is placed beneath the primary ground plane in addition to the main ground plane to improve radiation efficiency and antenna stability.

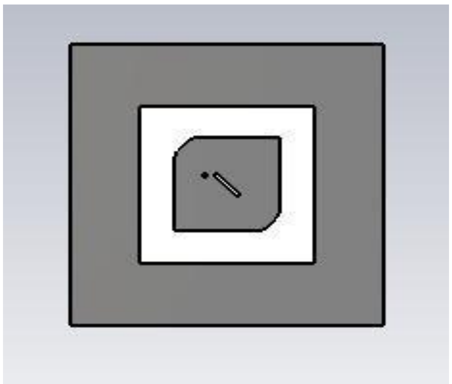

Fig 4.1 Antenna Design

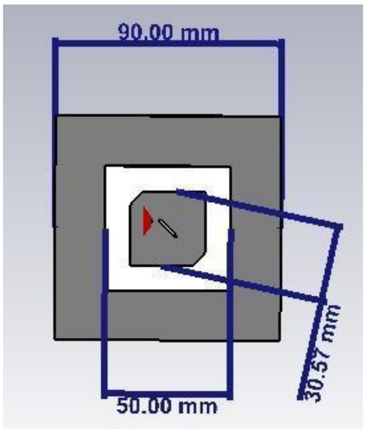

Fig 4.2 Dimension of Antenna

In order to maximize signal strength and coverage, the coaxial feed in the design is carefully calibrated to improve gain.The design seeks to improve impedance matching, radiation pattern, and overall antenna performance by truncating and blending the square patch antenna in addition to adding a slot and an extra ground plane. In order to maximize efficiency and reliability and satisfy the criteria of the 2.4 GHz ISM band, much consideration is given to the choice of materials and dimensions.

The antenna's gain is maximized by iterative design modifications and feed position optimization, guaranteeing peak performance for its intended use in wireless communication systems. Fig 4.2 and Fig 4.3 depicts the antenna design and dimension of the Antenna. In general, the suggested antenna design offers a thorough method for reaching the 2.4 GHz frequency range's high performance and efficiency, which is necessary for a variety of wireless communication applications.

DESIGN PARAMETERS:

1.Calculating the width of the main patch or radiator(W):

$$W=\frac{c}{2f_r}\sqrt{\frac{2}{(\epsilon_r+1)}}$$

2.Calculating the effective dielectric constant (ϵ_{reff}):

$$\epsilon_{reff}=\frac{(\epsilon_r+1)}{2}+\frac{(\epsilon_r-1)}{2}(1+\frac{12h}{w})$$

3. Calculation of the length of the main patch/radiator(L):

$$L=\frac{c}{2f_r\sqrt{\epsilon_{refff}}} - 2\Delta L$$

$$\Delta L=0.412h\left[\frac{\epsilon_{reff}+0.3}{\epsilon_{reff}-0.258}\right]\frac{\frac{w}{h}+0.264}{\frac{w}{h}+0.8}$$

4. Length of the feed line(L_f):

$$L_f=\frac{\lambda g}{4}$$

RESULTS AND DISCUSSIONS

When examining antenna performance, a number of important factors are considered in order to determine how well-suited the device is for a certain use case. Directivity, radiation pattern, VSWR (Voltage Standing Wave Ratio), realized gain, and reflection coefficient are some of the most important parameters taken into account.

5.1.REFLECTION COEFFICIENT(S11):

The reflection coefficient, indicating impedance mismatches in antennas, crucially affects signal loss and matching efficiency. At 2.4 GHz ISM band, a low reflection coefficient, such as the measured -19 dB return loss in Figure 5.1, signifies minimal signal loss and effective power transmission into the antenna system, showcasing excellent impedance matching.

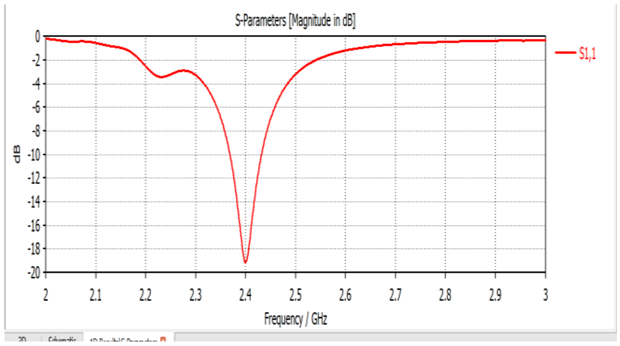

Fig 5.1 Reflection Coefficient (S11)

Analyze the reflection coefficient (S11) across frequencies to assess antenna impedance behavior, particularly focusing on the 2.4 GHz ISM band. A sharp decline in the reflection coefficient curve at 2.4 GHz signifies optimal impedance matching, affirming the antenna's suitability for ISM band applications. Achieving a return loss of around -19 dB at this frequency exceeds the standard threshold of -10 dB for medical antennas, ensuring dependable operation.

This work assists antenna designers in fine-tuning parameters for optimal performance and seamless integration into the 2.4 GHz frequency band, vital for various wireless communication applications.

5.2.REALIZED GAIN:

Realized gain quantifies an antenna's efficiency in transmitting or receiving electromagnetic signals relative to an ideal isotropic radiator, considering system losses. Our project yielded a realized gain of 2.884 dB, indicating intensified electromagnetic energy emission in specific directions compared to isotropic radiation. This directional concentration enhances signal strength and coverage in those specific directions, crucial for various applications.

The realized gain value of 2.884 dB showcases the antenna's favorable performance, surpassing the isotropic radiator's output. Through meticulous antenna design and tuning, this gain can be further optimized for enhanced coverage and directional effectiveness, meeting diverse application needs.

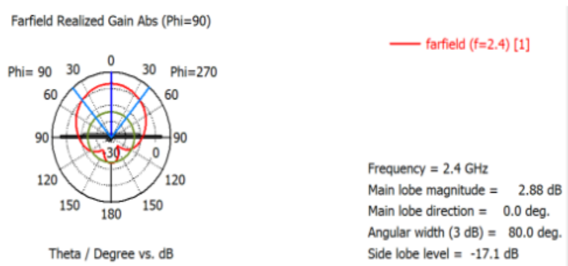

Fig 5.2 Realized Gain.

Figure 5.2 illustrates the realized gain specifically at the 2.4GHz frequency band. Our gain of 2.884 dB falls within the ideal range of 2-6 dB, affirming its suitability for antenna design purposes. This data provides valuable insights for engineers aiming to optimize antenna performance and achieve desired directional characteristics.

5.3 VSWR:

VSWR (Voltage Standing Wave Ratio) measures the ratio of the maximum to minimum voltage along the transmission line connected to an antenna, indicating impedance matching and signal loss. At 2.4 GHz, an ideal VSWR of 1 signifies perfect impedance matching between the antenna and the transmission line, ensuring efficient power transfer with minimal reflection.

A VSWR of 1 indicates that all power sent to the antenna is efficiently transmitted, with no reflected power. This condition, known as ideal impedance matching, occurs when the antenna's impedance precisely matches that of the transmission line or system it connects to. Achieving a VSWR of 1 at 2.4 GHz in antenna design is ideal, ensuring optimal power transfer efficiency and minimal signal loss.

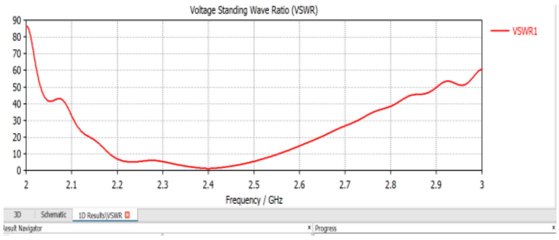

Fig 5.3 Simulated Plot of VSWR

Figure 5.3 illustrates the simulated output of VSWR, providing engineers with valuable insights into antenna performance. This optimal VSWR at the intended frequency validates the antenna's effectiveness for reliable wireless communication, ensuring dependable operation and efficient power utilization.

5.4 DIRECTIVITY:

Directivity describes how concentrated the emitted power is in one direction as opposed to an isotropic radiator. The measurement, which is commonly expressed in decibels (dBi), indicates the antenna's ability to focus electromagnetic radiation in particular directions. Increased directivity which indicates stronger radiation in a specific direction may be advantageous for applications requiring long-range communication or signal identification. In Figure 5.4, the Directivity simulated plot is displayed.

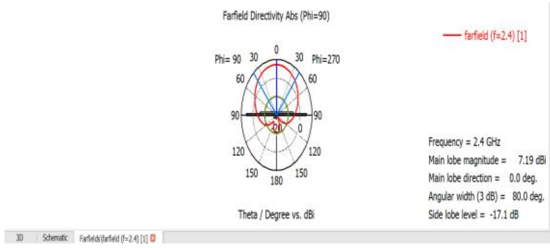

Fig 5.4 Simulated Plot of Directivity.

5.5 RADIATION PATTERN

The radiation pattern represents how the antenna sends and receives electromagnetic energy in three dimensions. Sidelobe levels, beamwidth, and antenna coverage may all be understood with the help of this diagram, which displays the distribution of radiated power by direction. By looking at the radiation pattern, engineers may adjust the antenna design parameters to get the desired coverage and performance features.In Figure 5.5, the output of the Radiation Pattern is displayed.

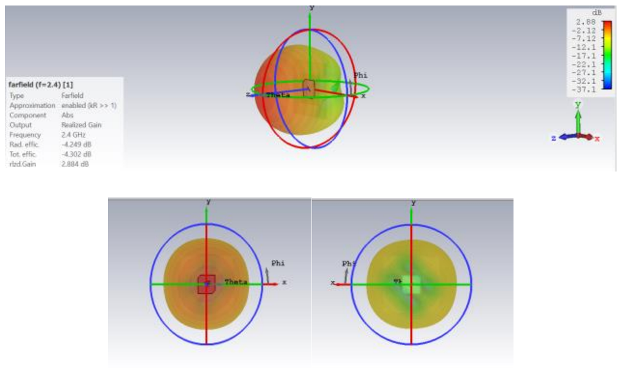

Fig 5.5 Radiation Pattern of Antenna

CONCLUSION:

Wearable electronics, particularly Wireless Body Area Networks (WBAN), have seen significant growth, catering to healthcare, communication, and monitoring needs mainly cancer detection . Overcoming challenges like coupling with the human body, a novel microstrip patch antenna design has emerged. Featuring a 50 × 50 mm square patch resonating at 2.4 GHz, it utilizes FR-4 substrate and PEC material. Enhancements include diagonal blending, truncation, and a central slot, alongside a secondary ground plane. Careful coaxial feed calibration improves gain and coverage. Simulated with CST Microwave Studio, the antenna achieves a realized gain of 2.88dBi, low VSWR, and wide bandwidth, ensuring efficiency and reliability with a reflection coefficient of -19dB for 2.4 GHz ISM band applications.

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