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Bio-Medical Antenna Design

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Abstract:

This paper introduces a circular patch antenna with an H-shaped slot tailored explicitly for wearable biomedical telemetry applications. This antenna, optimized for medical purposes, operates at a frequency of 2.4 GHz and is crafted using FR4 substrates. Its relative dielectric constant (Er=4.4)makes it an ideal candidate for seamless integration into wearable medical devices. The strategic integration of the H-shaped slot within the circular radiating patch enables precise resonance at 2.4 GHz frequencies. This ingenious design yields a noteworthy 10-dB bandwidth and sustains an impressive gain range of 21dBi. The utilization of the Aperture Coupling feeding technique significantly contributes to the antenna's heightened gain. Rigorous simulations conducted on HFSS (High-Frequency Simulation Software) validate the antenna's robust performance, affirming negligible deviations in reflection coefficient, bandwidth, gain, and efficiency. This pioneering antenna design exhibits considerable promise for integration into wearable biomedical devices due to its compact form, superior performance, and minimal interference with the human body.

Keywords: Circular patch antenna, Aperture Coupling, H-Shaped slot patch, *HFSS*

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I. INTRODUCTION

The world of wearable technology has been experiencing significant growth, especially in the realm of health monitoring systems. This trend is not only evident in regular wearables but also in implantable devices designed for various healthcare applications such as endoscopy, neural recording, glucose monitoring, and intracranial pressure monitoring. As wearable communication devices strive for broader bandwidths to support various functionalities, concerns about specific absorption rates (SAR) on the skin's surface have emerged as a top priority. SAR refers to the rate at which energy is absorbed by the body when exposed to radiofrequency electromagnetic fields. High SAR levels can pose potential risks to human tissues, necessitating careful consideration in the design and deployment of wearable technologies.

Achieving a balance between multi-band capability, minimizing interference from the human body, and adhering to strict safety standards set by organizations like the International Commission on Non-Ionizing Radiation Protection (ICNIRP) presents a significant challenge for researchers and developers in this field.

Traditionally, microstrip patch antennas have been commonly used in wearable designs due to their flat, planar configuration. However, these designs often encounter issues such as impedance mismatch caused by interaction with the human body and narrow fractional bandwidths. To address these challenges, researchers have been exploring various innovative approaches

FractalAntennas: Fractal antennas are characterized by their self-similar geometry, allowing for enhanced bandwidth and miniaturization. By leveraging fractal geometries, researchers can design antennas that exhibit improved impedance matching and broader bandwidths compared to traditional designs.

Low-profile CPW-fed Slot Antennas: Coplanar waveguide (CPW)-fed slot antennas offer advantages such as low profile and ease of integration into wearable devices. By optimizing the design parameters, researchers can achieve improved performance in terms of bandwidth and radiation efficiency while minimizing interference from the human body.

Fabric Substrate Antennas: Antennas made with fabric substrates present a promising solution for wearable applications, as they offer flexibility, comfort, and seamless integration with clothing. By incorporating conductive fabrics or threads into the antenna design, researchers can develop lightweight and conformal antennas that maintain performance e--ven when in close proximity to the human body.

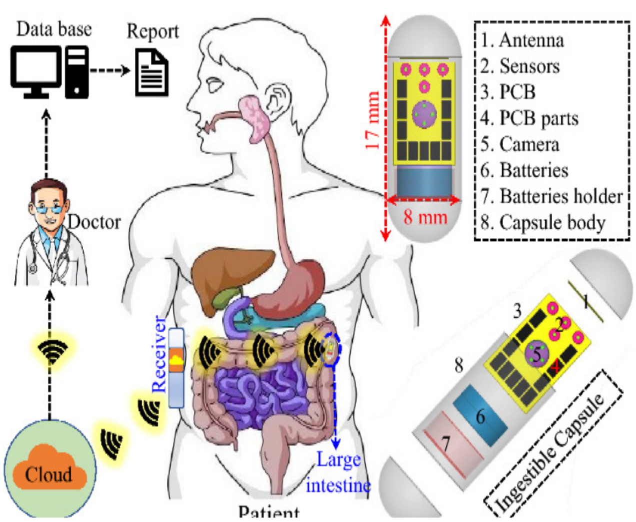

Fig. 1operation of Antenna in data transmission

II. Literature survey

In the paper proposed byXu-bao Sun[32]presentsa design of a rectangular microstrip slot antenna, fed by a microstrip line, is introduced to attain a notably broad bandwidth on a thin substrate. This achievement is realized through the integration of a rectangular slot within the ground plane, coupled with the utilization of a perpendicular microstrip line. Furthermore, an additional square slot in the ground plane contributes to the wideband properties of the antenna. Both simulated and measured outcomes demonstrate a 36% fractional impedance bandwidth centred at 2.4 GHz, along with consistent radiation patterns across varying frequencies.

In the paper presented byJaget Singh[33] presentsan inset feed microstrip patch antenna is to boost return loss and bandwidth. The suggested antenna uses RT-Duroid5880, which has a dielectric constant of 4.4, as its substrate. The dielectric constant of RT-Duroid5880 is the lowest and it can lower the dielectric Microstrip patch antenna losses are related. The 2.4 GHz frequency band, also known as the Industrial, Scientific, and Medical (ISM) band, is where this antenna is beneficial. At the intended frequency of 2.4 GHz with an 80 MHz bandwidth, the designed antenna displays a return loss of -40.5 dB and a gain of 6.69dBi. Impedance matching and return loss are improved by the inset feed and slot.

In the paper proposed by C. Liu, Y.-X. Guo, and S.Xiao[28] presents a single-fed miniaturized circularly polarized microstrip patch antenna is designed and experimentally demonstrated for industrial-scientific-medical (2.4-2.48 GHz) biomedical applications.It is designed by utilizing the capacitive loading on the radiator with has the advantage of good size reduction and good polarization purity. The simulated impedance, axial ratio, and radiation pattern are studied and compared in two simulation models: cubic skin phantom and Gustav voxel human 0body. The simulated and measured impedance bandwidths in cubic skin phantom are 7.7% and 10.2%, respectively.

In the paper proposed by D Anand Kumar, R G Sangeetha[34] presents the aperture coupled

Microstrip Patch Antenna (AC-MPA) is specifically engineered for long-range air surveillance radars covering approximately 400 km. It operates within the 1 GHz to 2 GHz frequency range (D-band). The design employs aperture-coupled power feeding, which is critical for achieving wideband behaviour, improved return loss, gain, Voltage Standing Wave Ratio (VSWR), reduced compatibility issues, and a smaller physical footprint. In the aperture-coupled feeding technique, the input signal is coupled to the radiating patch through an aperture (slot) present on the ground plane of the feed line. This method differs from traditional microstrip patch antennas. The design and implementation of the aperture-coupled patch antenna are thoroughly analysed in terms of various parameters including return loss, gain, efficiency, directivity, and power parameters. These metrics are then compared with the performance of an inset line feeding approach. The proposed design demonstrates significant advantages over inset line feeding. It achieves a gain of 5 dB, directivity of 4.5 dB, efficiency of 30%, and an impedance bandwidth exceeding 15% with a centre frequency of 1.5 GHz. Moreover, the maximum return loss reaches -40 dB, a notable improvement compared to the -19 dB typically obtained with inset feed line microstrip patch antennas, thanks to proper impedance matching.

III. EXISTING PROBLEM

The current biomedical antennas we have are not great when it comes to being easy to wear and they don't perform as well as they could. The main issues are that they're not very small and don't provide a good balance between bandwidth and gain.Right now, the antennas use a frequency of 2.4 GHz with a gain of only 3dBi, which isn't enough. We need to make some improvements, especially in increasing the gain. Also, the way we feed the antenna plays a big role in how much gain it can have. So, we really need to work on making these antennas more compact, improving the balance between bandwidth and gain to create a better biomedical antenna system.

IV. PROPOSED SOLUTION

We've crafted a special kind of antenna for medical use, operating at a frequency of 2.4 GHz, fitting right into the Industrial, Medical, Scientific band. What makes it stand out is its impressive bandwidth of 500 MHz and a gain that's over 21.1dBi, ensuring strong and reliable performance. The antenna itself has a circular patch and uses a clever feeding technique called Aperture Coupling. To boost its performance, we've added an H-shaped slot, which significantly enhances its ability to capture and transmit signals effectively. This design is more than just technical details; it's a careful balance of safety and functionality, ensuring that our biomedical antenna not only works well but also prioritizes the well-being of those who use it.

In this we proposed three designs, which we tried different design patterns with various structures and feeding techniques to gain desired output. Finally, we concluded with Circular shaped with H shape slot and aperture coupling feeding technique Aperture Coupling in antenna design. It enables us to get high gain at frequency inISM (Industrial, Scientifical and Medical). The Designs we made are mentioned below

1. Circular patch antenna with rectangular slot and Aperture coupling Feeding technique.
2. Circular patch antenna with H shape slot and Aperture coupling Feeding technique.

V. CIRCULAR PATCH WITH RECTANGULAR SLOT

In this design, we used Circular patch which is radiating material and aperture coupling as feeding technique and slot is rectangular shape. This design comprises of Substrate material as FR4 Epoxy. The Dielectric constant is 4.4. We used substrate above and below the ground which is part of aperture coupling Slot is injected at ground, where the two substrates are radiating materials. Input impendence is maintained as 50 ohms.

Name	**Value**
Height of substrate	1.6mm
Width of substrate	100mm
Length of substrate	100mm
extension	0mm
Width of feed	50mm
Length of feed	3mm
Radius	22mm
Width of port	3xwfeed
Height of port	5xh sub
Width of slot	6mm
Length of slot	3mm

Fig 2 Design Parameters

Area of rectangular patch = Area of circular patch

Length × Width = $\boldsymbol{\pi * R^2}$

Radius = $(\frac{L*W}{\pi})^{1/2}$

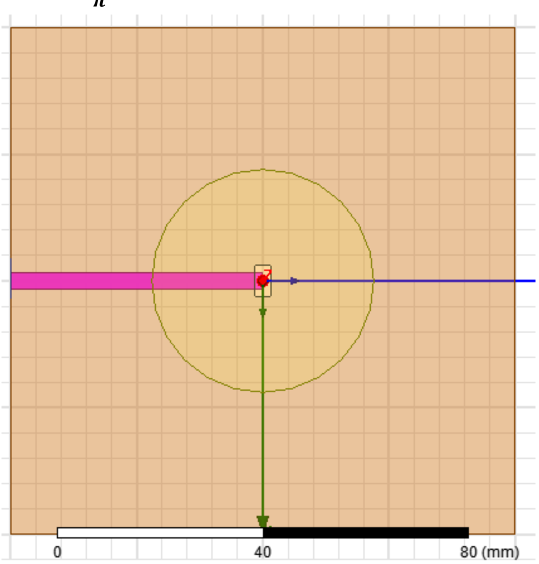

Fig 3 Circular patch Antenna with rectangular slot

Above design is designed in HFSS with the rectangular slot, the antenna has the source(Wave Port).

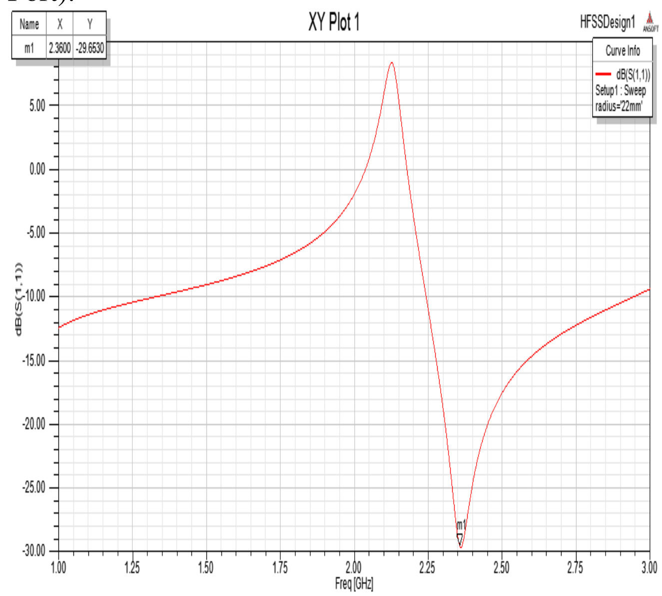

Fig 4 Frequency of operation with rectangular slot

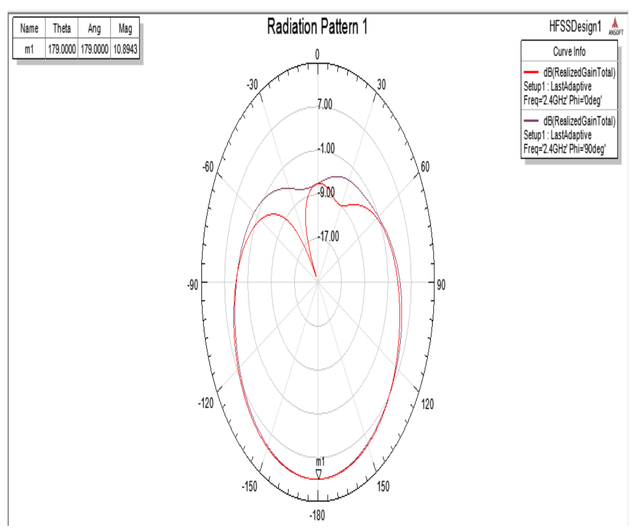

Fig 5 Gain plot of rectangular slot

VI. CIRCULAR PATCH WITH H-SHAPE SLOT

In this design we used Circular patch which is radiating material and aperture coupling as feeding technique and slot is rectangular shape. This design comprises of Substrate material as FR4 Epoxy. The Dielectric constant is 4.4.

Name	Value
Height of substrate	1.6mm
Width of substrate	100mm
Length of substrate	100mm
extension	0mm
Width of feed	2mm
Length of feed	3mm
Radius	22mm
Width of port	3xwfeed
Height of port	5xh sub
Width of slot 1	6mm
Length of slot 1	3mm
Width of slot 2	0.5mm
Length of slot 2	10mm

Fig 6 Design Parameters

We used substrate above and below the ground which is part of aperture coupling Slot is injected at ground, where the two substrates are radiating materials. Input impendence is maintained as 50 ohms.

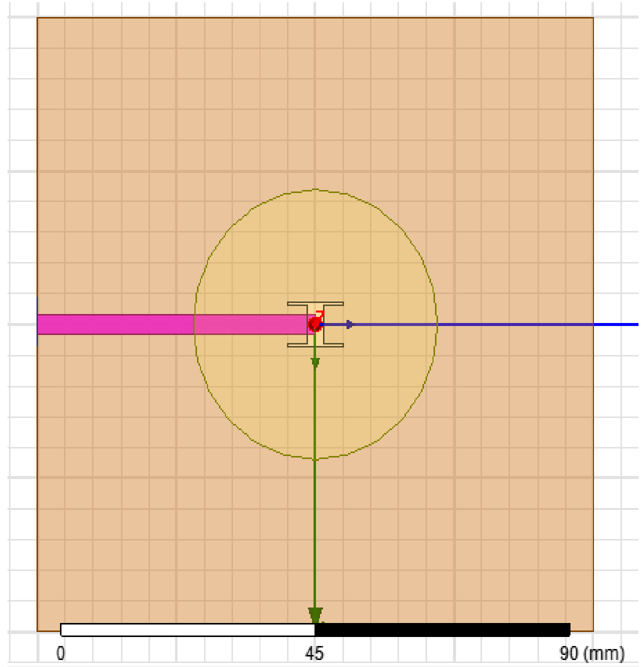

Fig 7 Circular patch Antenna with H shaped slot

Above design is designed in HFSS with the H shaped slot, the antenna has the source (Wave Port).

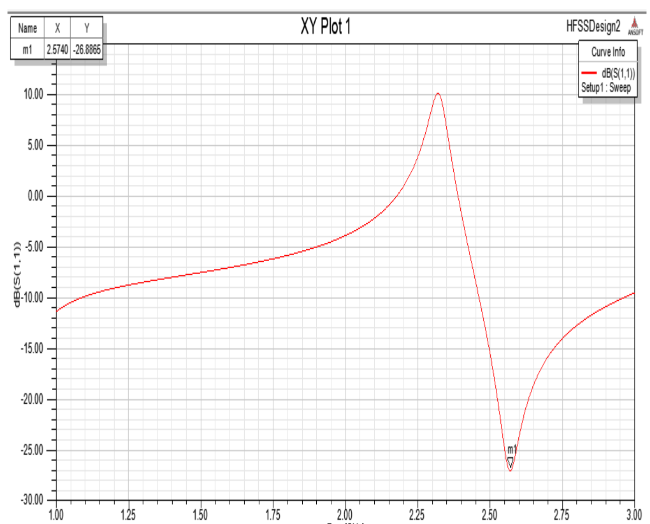

Fig 8 Frequency of operation with H shaped slot

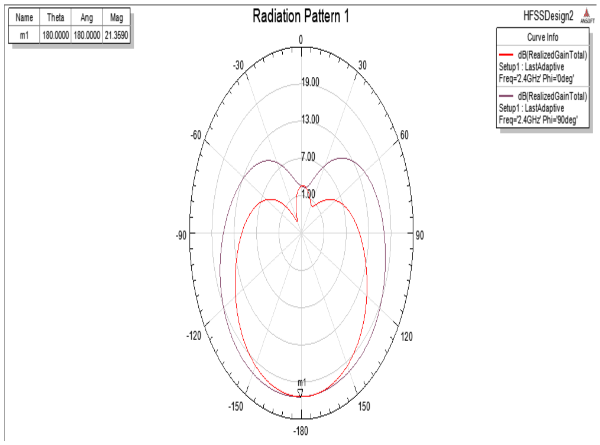

Fig 9 Gain plot of H shaped slot

VII. CONCLUSION

Our proposed work with the antenna design in HFSS which is circular patch H shape slot with Aperture coupling Feeding technique results in 21.4dBi gain where we have 11dBi enhancement from circular patch with rectangular slot and bandwidth unlike previous design. The frequency 2.4Ghz used in this project falls in range of Industrial, Scientific, medical band. The gain 10dBi is increased when the slot changes. While designing antenna we ensure to have impedance matching and frequency to follow ISM band. Even though the designed antenna resulted in reasonable gain and bandwidth unlike the referenced design, bandwidth should be increased. In the High frequency of operation, we have encountered higher losses even though we got the good gain, it should be reduced. SAR value should try to reduce.

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