Wearable Antenna For Tracking Applications

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Abstract:- Wearable antennas play a major role in military applications. Antennas are required to track the current location of the soldiers, but the rigid structure of the antenna makes it uncomfortable for the soldiers to move. To avoid this, a flexible type of antenna is designed. The major concern in flexible antennas like textile antennas is frequency-detuning problems in the operation brought on by structural distortion. When the antenna is distorted, it might not function at the intended frequency. In order to rectify frequency-detuning issues, a 1.8 GHz fabric antenna is presented in this work for GPS tracking applications with faulty (defective) ground structures. Therefore, in situations with a broader bandwidth and adequate antenna performance, the impacts of frequency detuning could be reduced. The rectangular slots are attached to the ground to form a defective ground structure, and a fabric antenna measuring 90 mm (L) by 100 mm (W) is designed. Copper and jean fabric are used as conductive materials and substrates, respectively. A detailed analysis with DGS is performed on the antenna. The importance of DGS in the proposed design is clarified by comparing the electric and magnetic field strengths at both radiating and non-radiating edges. Comprehensive analyses of performance are conducted using S-parameter, gain, radiation pattern, and current distribution. Thus, in both bending circumstances, the antenna is able to operate at the required frequency.

Keywords:- *Wearable textile antenna, bending, defective (faulty) ground structure (DGS).*

1 Introduction

By combining materials and electronics to improve clothing functioning, wearable technology such as smart clothing has great promise for enhancing the quality of life. The wearer can experience wireless body communication for a wide range of applications, including sports, entertainment, medical, navigation and tracking via GPS, and even some specialized jobs like firefighting and the military. This is made possible by the revolution in smart clothing. As a means of sending and receiving radio waves, wearable devices require antennas in order to facilitate various forms of wireless communication, including in-body, on-body, and off-body communication. A wearable antenna needs to be thin, flexible, and simple to incorporate into clothes made of fabric or other similar materials. Typically, a common fabric is used to build a wearable antenna, and a radiating element such as copper materials, conductive spray, or adhesive film is then integrated. After frequent usage or washing, the antenna can be readily detachable from the fabric, which will reduce its efficiency and have an impact on its performance because the conductive material will dissolve from the fabric. Mechanical deformations, such as bending, are inevitable for textile-based antennas. Because bending results in a change in the impedance characteristic, it is known to deteriorate the antenna's performance, including its gain and bandwidth, and to potentially alter its resonant frequency for the proposed application. In the worst-case scenario (a severely bent E-plane state), input matching that is no longer functional may cause frequency to vary from the intended application. Wideband operation is therefore suggested as a way to reduce the effect and preserve the antenna's performance during bending, guaranteeing that the resonant frequency stays within the operational range even after bending. This analysis is restricted to H-plane bending. The increased bandwidth suggested in this paper will help wearable fabric-based GPS antennas that are experiencing frequency detuning. In wearable applications, a variety of methods have been employed to enhance antenna bandwidth, including modified patches, slots, and slits. Additionally, the Defective Ground Structure (DGS) approach can be used to increase bandwidth. This approach is among the best options since it creates the etched slits or faults on the ground, which is ideal for the suggested design. A planar antenna with bandwidth extension employing a Defective Ground Structure (DGS) is devised in order to address the issue of frequency detuning. The gain, radiation pattern, and resonant frequency of the antenna under E-plane bending conditions were examined in order to conduct the analysis. The 1.8 GHz frequency is chosen for the antenna's GPS use. ANSYS, a 3D electromagnetic program, is used for all simulation work, and the outcomes are validated. In the free space field, numerical and experimental measurements are made of the attained S-parameters, currents, and field distributions of the slotted ground surface and the radiating elements.

2 Design

The antenna's larger bandwidth design helps to solve the textile-based wearable GPS antenna's frequency-detuning issue. In wearable applications, a variety of methods have been employed to enhance antenna bandwidth, including slits, slots, and altered octagonal patches. Bandwidth is also improved by using the Defective Ground Structure (DGS) method. Because the slots or faults are formed on the ground, this procedure is among the best ones for the suggested design. Therefore, to solve the problem of frequency detuning, a bandwidth-extended planar antenna using a defective ground structure (DGS) is proposed.

The antenna is designed with an area of 90 x 100 mm. The radiating element and antenna substrate are chosen with a dielectric constant of ε_r 1.6, respectively. The antenna was designed with a 1.8 GHz frequency for GPS applications. The dimensions of the antenna are given in Table 1. The top and bottom view of the antenna is shown in the Fig 1 and 2 respectively.The proposed design is depicted in the Fig 3.In order to reduce manufacturing error during antenna fabrication, which can lead to impedance mismatch as well as reduce performance, a coaxial feed approach is employed. On the ground plane, rectangular slots have been created in order to expand the bandwidth.

When a defective ground structure (DGS) is used to modify the antenna's ground structure, parametric analysis is used to look at the properties of the proposed antenna. To reduce the effects of tuning, base layer modifications are performed to enhance the bandwidth. Theoretically, a micro-strip antenna's metal component is made up of resistance, inductance, and capacitance. Therefore, the defect area will disrupt the earth's surface current distribution when the DGS is incorporated on the ground plane beneath the transmission line. Also, the addition of slots to the ground plane modifies the effective inductance, capacitance, and resistance values of the transmission line.

The analysis is carried out by looking at the bending-related properties of the antenna, such as the radiation pattern, gain, and resonant frequency in both H- and E-plane bending situations. Cylindrical bending performance analysis of bandwidth-enhanced electro-textile antennas with a radius of 42.5 mm and a bending angle of approximately 135 degrees, which represents the bending condition around a human arm, is being used. The 3D electromagnetic program HFSS is used for all simulation work, and the outcomes are validated. In the free space field, the obtained S parameters, currents, and field distributions of radiating elements and ground planes with different slots are measured both experimentally and numerically.

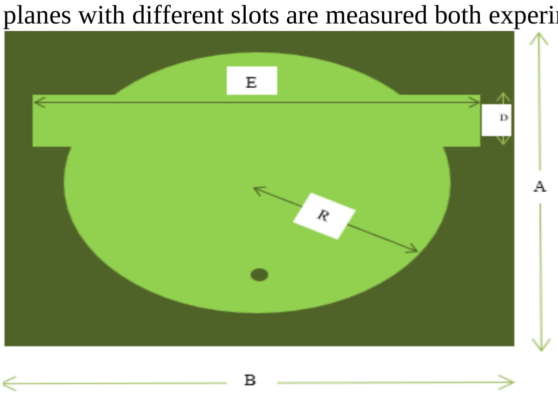


Fig 1 : Top view

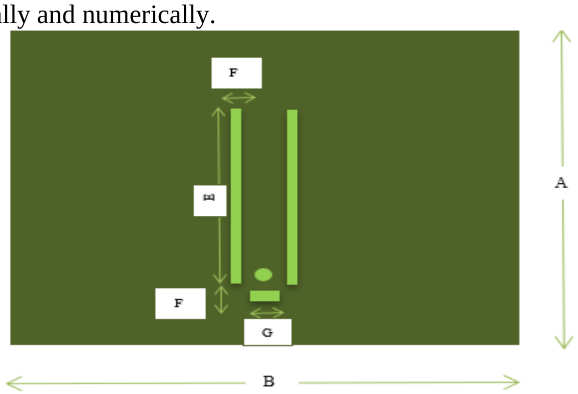


Fig 2 : Bottom view

Table 1

Parameters	Dimensions (in mm)
A	90
B	100
C	90
D	15
E	45
F	3
G	18
R	38

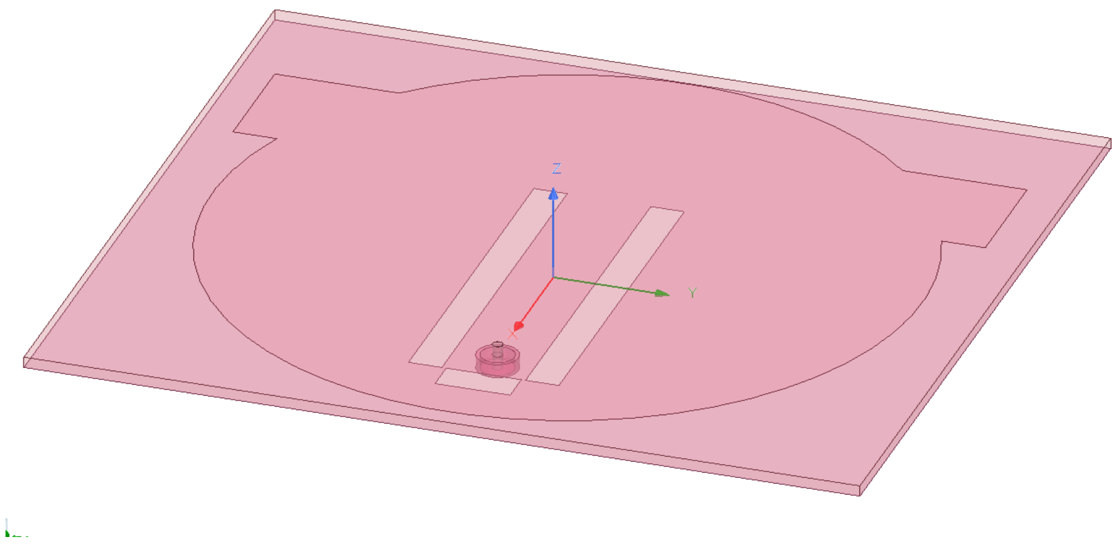


Fig 3: Proposed design

3 Parametric analysis

1) Slot locations

With relation to the coaxial probe location, the slots at the surface of the planes are positioned beneath the patch. In order to purposefully disrupt the current distribution on ground plane, current at the coaxial probe point is much higher. Consequently, it is possible to regulate the electromagnetic wave's excitation and propagation through the substrate layer. The slot is situated as illustrated in the Fig 2. Nevertheless, the slot is about half as good as it was when positioned horizontally both above and below the coaxial probes.Additionally, there is shift in resonant frequency, which becomes more pronounced when slot is positioned above coaxial probe.

2) Count of slots

To enhance the bandwidth of the antenna, more slots are added. The positioning of the two slots vertically between the coaxial probe enhances bandwidth. It is evident from the present distribution that the inclusion of slots has further disrupted the current flow, and the S11 is above -10 dB, hence the antenna is less effective. Next, employing two slots positioned horizontally in between the coaxial probe, another attempt is made. As the bandwidth is still narrow, the result indicates no changes in bandwidth. This is because the surface disturbance that happened in both slits appears to combine to form a single circular current, as evidenced by the current flow. The results are more significant than those of a single slit because the simultaneous concentration of two slits became one in the horizontal position. Expanding the bandwidth yields a more promising result with two vertical slots. For improved bandwidth performance, the base plane is thus given the third slot. The bandwidth is increased, and three current circulations are produced on the base plane by adding a third horizontal slot. On the other hand, the frequency is moved to the left, and the antenna runs in dual-band mode. Moreover, the coaxial probe rests beneath the third slot. With this change, the bandwidth was wide, and the S11 values were below -10 dB. This satisfies the prerequisite. Generally, the slots can be represented by an impedance network that can be built to expand the antenna bandwidth and offer a broadband response, as well as a simply reactive impedance. Parasitic capacitance is introduced when DGS is applied to the base plane, which results in an increase in the boundary field. The coupling between the conducting zone and the ground surface increased as a result of the parasitic capacitance, hence broadening the bandwidth. The longitudinal current flow is disrupted, and the current's direction changes whenever a slit is cut in the ground, increasing the bandwidth.The evolution stages in the slot fixing is shown in the Fig 4.

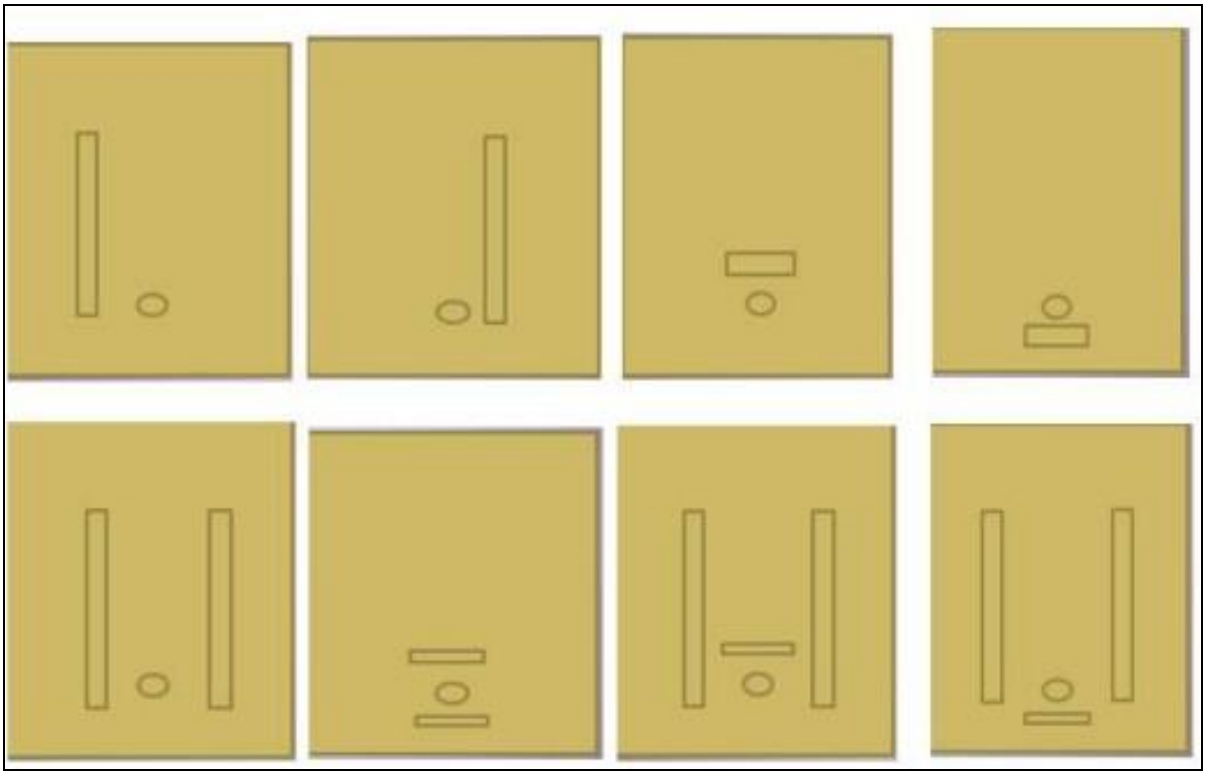


Fig 4: Fixing of modified ground slot

3) Separation between slots

To get wider bandwidth outcomes, the slot separation is looked into in this work. The coaxial displacement served as an estimate for the slot's location. A narrow bandwidth is indicated by a distance between 4 and 8 mm. The two slots are close to one another, so the current intensities build up. Only one current disturbance is created by the current as it flows through the antenna's core. Additionally, it was noted that the resonant frequency moves to the right when the slot spacing expands (from 4 mm to 10 mm). A higher frequency is achieved by shifting the distance, since increasing the distance between slots increases the effective inductance. Changes in bandwidth are calculated at slot spacings between 10 mm and 12 mm. The current can flow around the periphery of these separations, which may cause the current distribution to be disturbed and the magnetic field present at the slot to be amplified. But because the slot is too far away from the coaxial feed, the current distribution weakened, and the device was unable to generate a large bandwidth. Thus, 10 mm is thought to be the ideal distance for vertical slots based on S11's performance and the current distribution. Moreover, the vertical slits are maintained at a distance of 10 mm, while the horizontal slot distance from the coaxial probe is altered concurrently. The bandwidth may be found to be nearly identical by varying the horizontal slot's distance, although the S11 exhibits variations. When the horizontal slot recedes from the coaxial feed, the current flowing through the slots gets weakened. S11 becomes the lowest. Thus, as S11 is superior, 5 mm is determined to be the ideal horizontal slit distance. The S parameter analysis for the different slots, such as horizontal, vertical ('slot 1' at the left side of the coaxial feed), and vertical ('slot 2' at the right side of the coaxial feed), is shown in the below Fig 5.

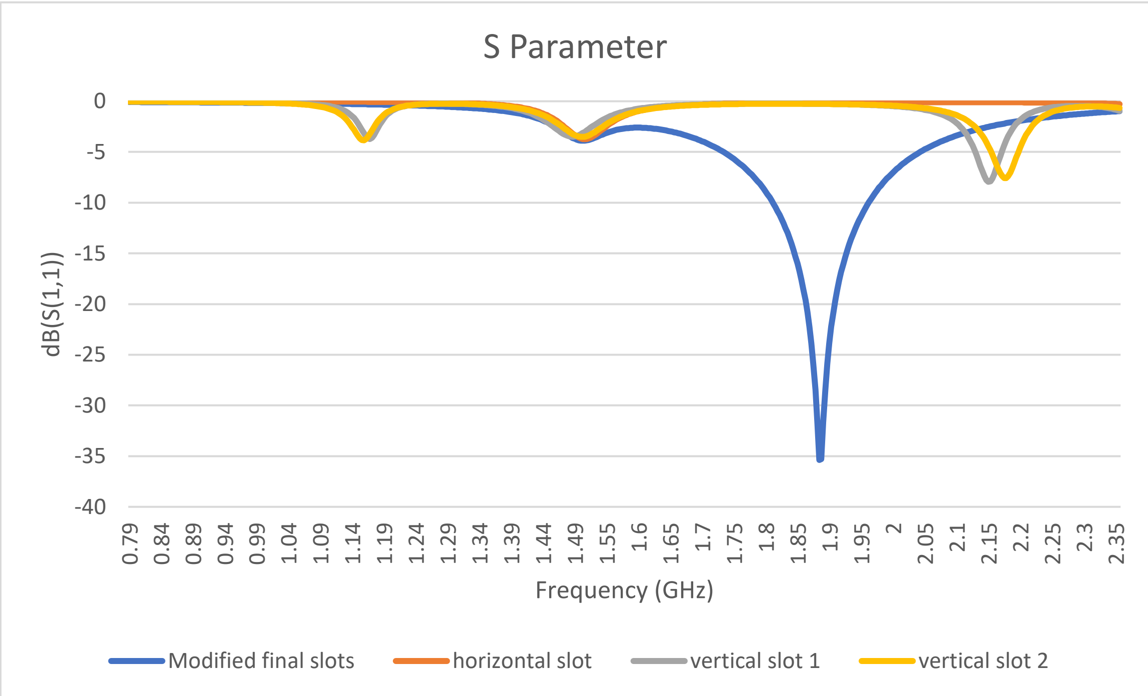


Fig 5: Analysis of S parameter

4 Results and discussion

This section gives a brief overview of the results obtained for the proposed design. Several antenna parameters, such as S11, VSWR, E-Field, and H-Field, have been evaluated.

1) S11 parameter

The operational range in the proposed design is 1.65–2.11 GHz, while the resonant frequency is 1.88 GHz. The bandwidth of the designed antenna is obtained at 467.2 MHz and it is shown in the Fig 6.

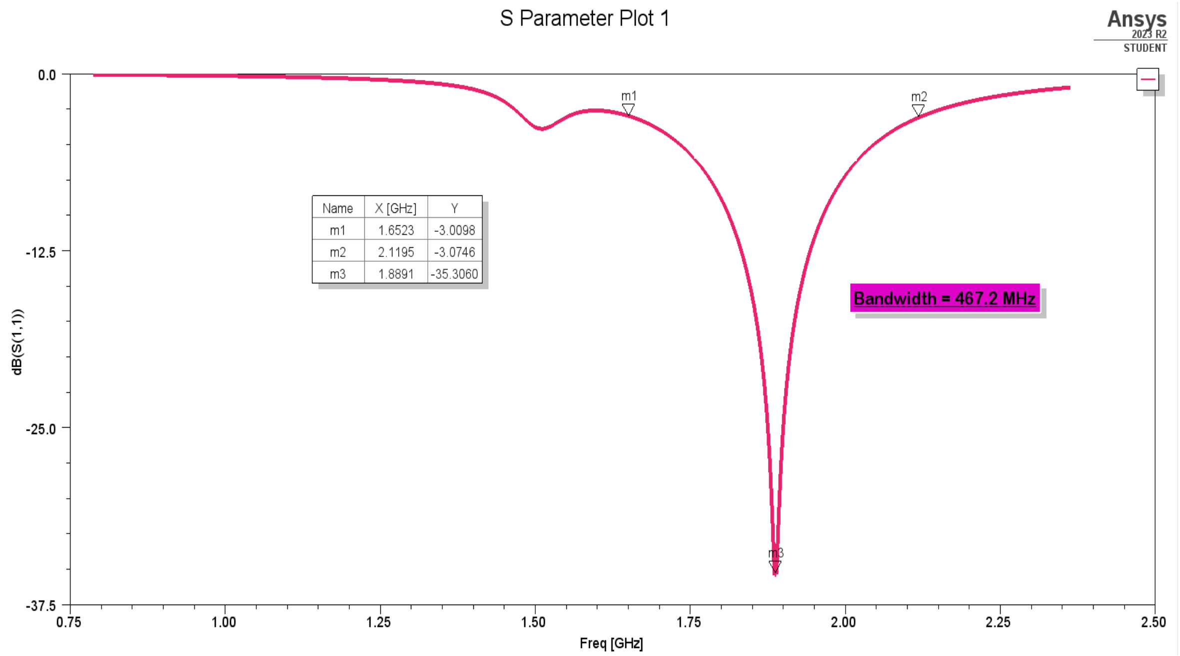


Fig 6: Reflection Coefficient along with the bandwidth

2) VSWR

VSWR indicates the amount of power that can be safely delivered to an antenna without damaging it. A low VSWR value means a better impedance match, and therefore more power is being transferred efficiently from the radio or transmission line to the antenna. In this graph (Fig. 7), the VSWR for the frequency of 1.8 GHz is obtained as 1.03.

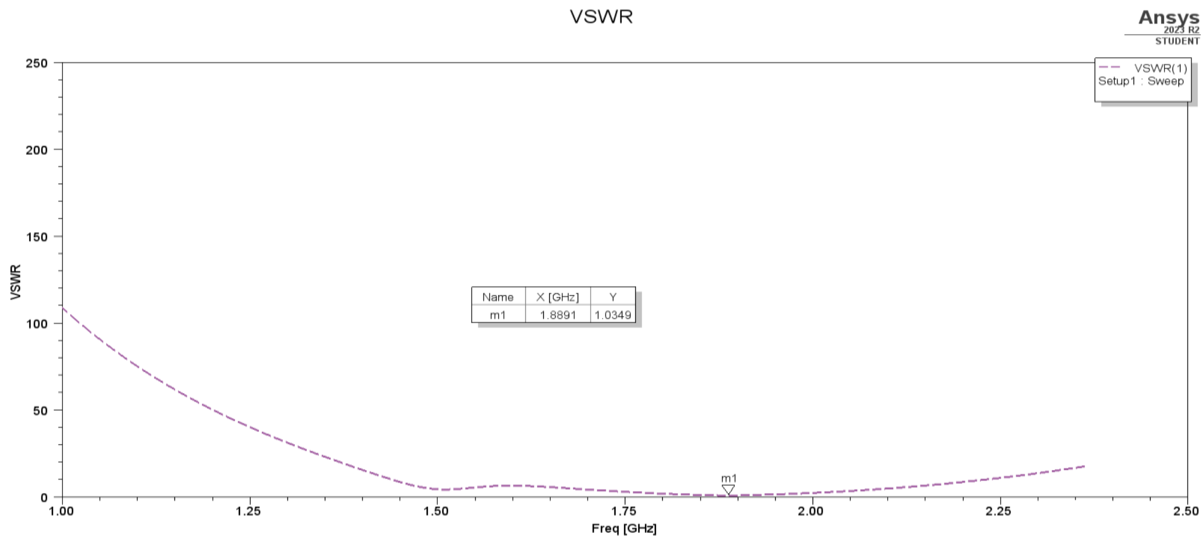


Fig 7: VSWR

3) Effect of field distribution

In this section, the distribution of E-Field (in the Fig 8) and H-Field (in theFig 9)S is discussed. It is also investigated how the E-field's distribution changes under bending conditions. The obtained E-plane bent condition is shown in Fig. 10. This illustrates the bending situation brought on by various bending events that happened during design. On the other hand, this has no appreciable impact on the antenna's performance.

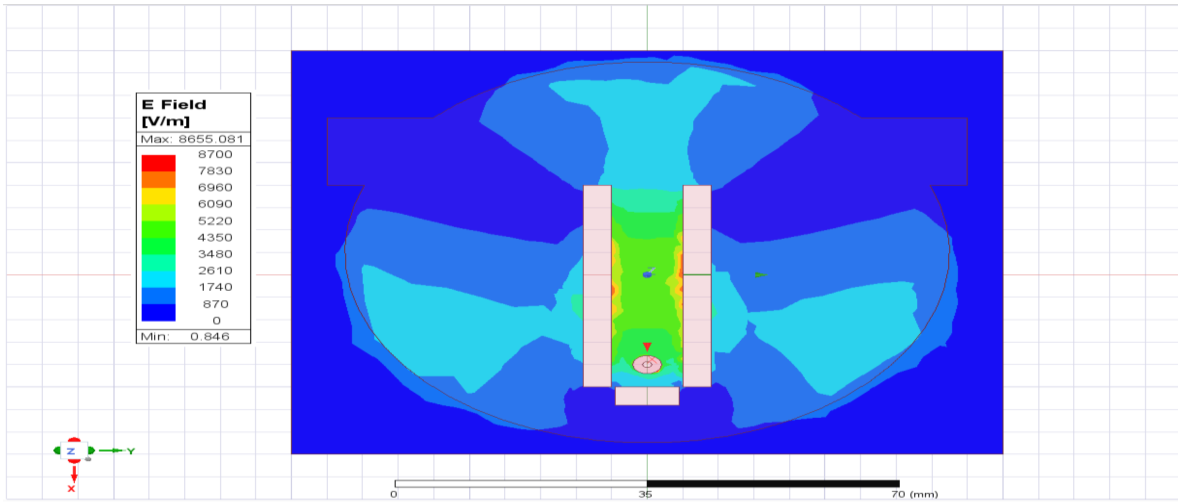


Fig 8: Distribution of E field

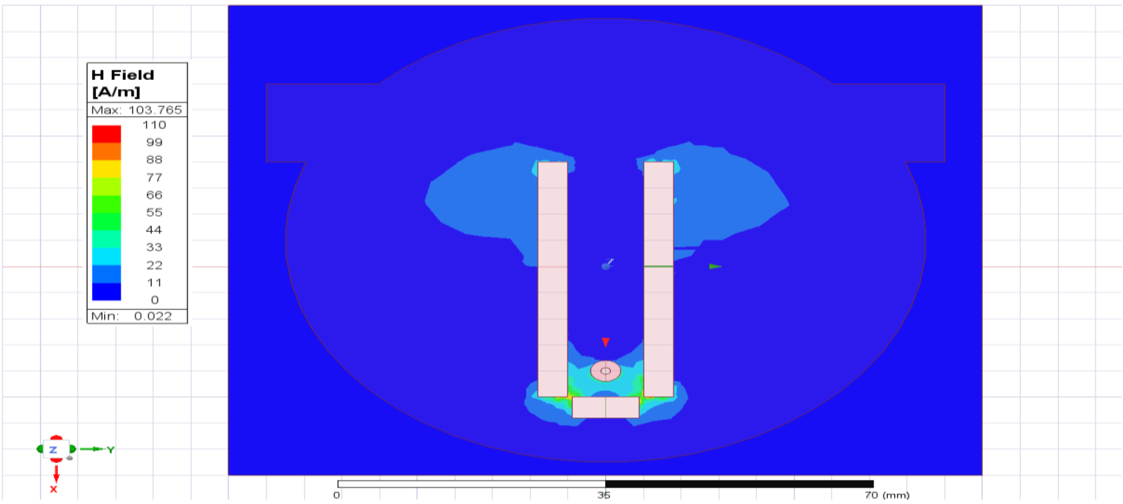


Fig 9: Distribution of H field

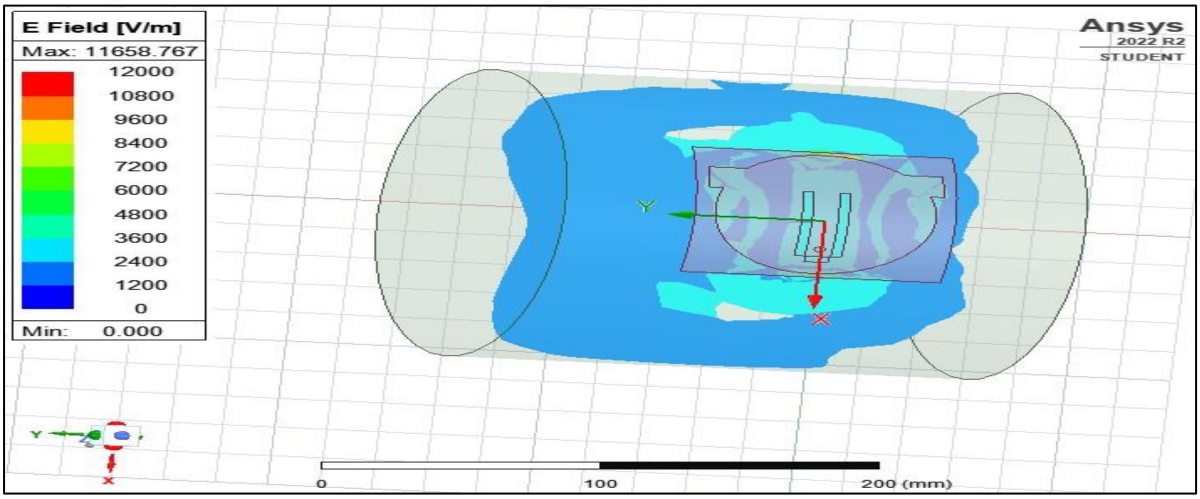
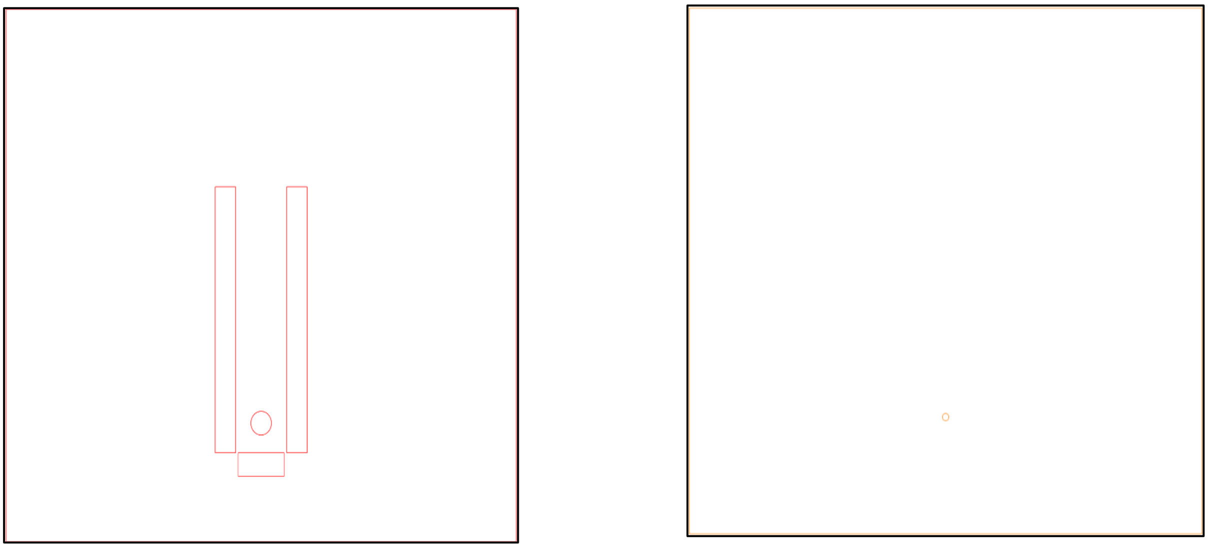


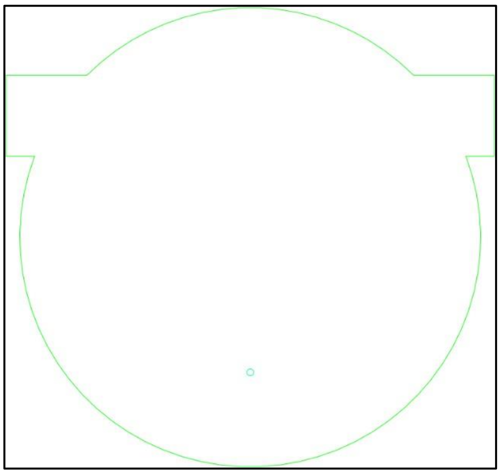
Fig 10: Bending frequency analysis

4) Fabrication of antenna

The antenna is fabricated with jean as the substrate and copper as the radiating element. To complete the fabrication process, it is converted to the DXF file format, which is helpful for putting the intended antenna into practice. The DXF format is shown in Fig. 11.The materials used for the antenna fabrication is shown in the Fig 12 and the fabricated antenna is depicted in the Fig 13.



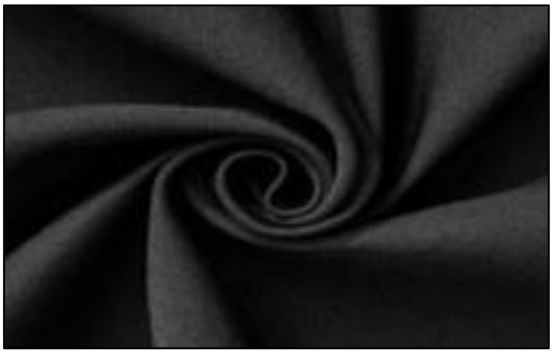
(a) (b)



(c)

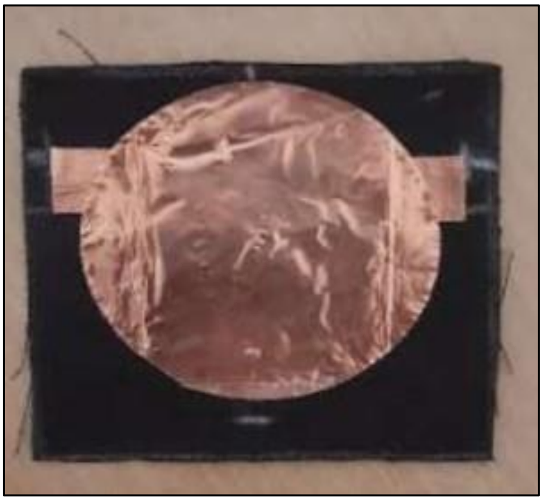
Fig 11: DXF file format (a)Ground, (b)Substrate and (c)Patch

(a)



(b)

Fig 12: Materials used to fabricate (a)-Copper roll and (b)-Jean Fabric



(a)

(b)

Fig 13: Fabricated Antenna (a)Top face and (b)Bottom face

5 Testing of the antenna

5.1 Components used

- Arduino UNO processor
- GPS Module

6.1.1 Arduino UNO processor

A well-liked microcontroller board in the design and electronics communities is the Arduino Uno. Based on the Atmega328P microcontroller, it has several connections for attaching sensors, displays, and other parts, as well as digital and analog input/output ports, inbuilt voltage regulation, and a USB interface for programming and communication. It's known for its simplicity and versatility, making it a great choice for beginners and experienced hobbyists alike to create a wide range of electronic projects.

6.1.2 GPS Module

A GPS (Global Positioning System) receiver refers to a GPS module or chip capable of receiving and processing signals from satellites in the GPS constellation at a particular frequency. It uses the timing and data from these satellites to calculate its precise location on Earth (latitude, longitude, and altitude) and provide accurate time information. The accuracy of a GPS receiver depends on various factors, including the quality of the receiver, the number of satellites it can track simultaneously, and its signal processing capabilities.

5.2 Implementation for testing

The connection is done with the above-mentioned components. With the help of jumping wires, the transmitter, receiver, power supply, and ground are connected between the Arduino and the GPS. The GPS has a patch antenna along with it. This patch antenna is removed by re-soldering it. In place of the patch antenna, the fabricated wearable antenna is replaced by providing coaxial probe feeding. After the connection, they are soldered with the designed antenna.

Fig 14: Connection with Arduino board and replacing the antenna of GPS

The Arduino is connected to the PC with the help of cable interfaces. To perform coding, there is a need for software called Arduino IDE, which helps to run and stimulate the code. This is written in the Arduino IDE in the C language to show the output in latitude, altitude, longitude, and time. A library called Tiny GPS is installed on GitHub. The blinking of light in the GPS module (shown in the Fig 14) confirms that GPS is connected and the signals are ready to transmit and receive at the desired frequency.The connection of the GPS module with the PC is shown in the Fig 15.

Fig 15: Connection of antenna along with the PC to trace the location

In Fig. 16, the serial monitor shows the outputs such as the latitude, altitude, longitude, and time of the current location. The accuracy of the location can be verified with the help of Google Maps. In Fig. 17, the map shows the location of the college from where the testing is done.

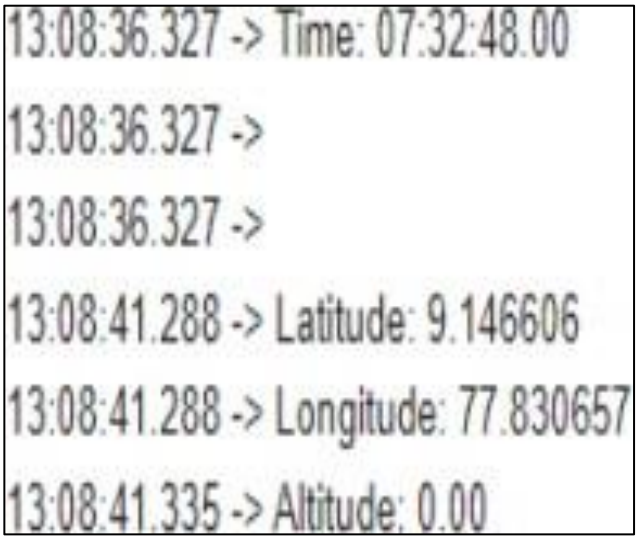


Fig 16: Output produced at the serial monitor

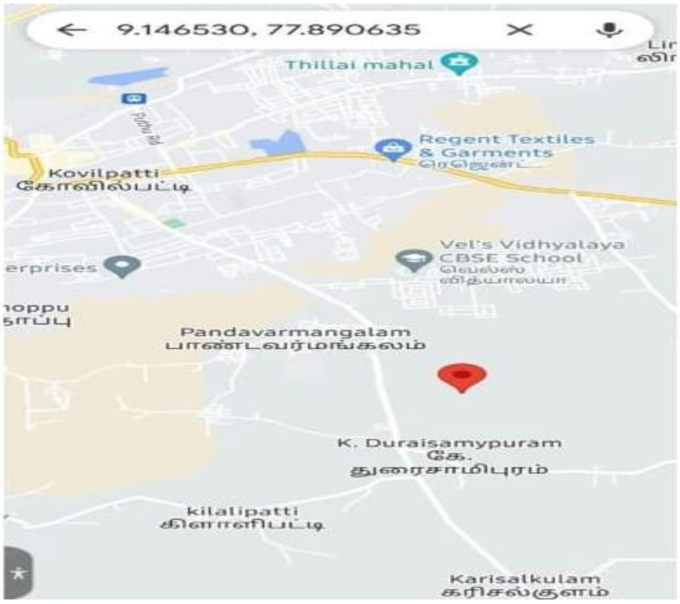


Fig 17: Location shown in Google Maps

6 Conclusion

The main focus of this study is the application of the wearable antenna for the tracking application. The wearable antenna has major concern of frequency detuning which affects the center operating frequency which has been studied in the paper thoroughly. The use of the modified ground structure has effectively reduced the detuning issues. The experiment was successful and the results have been verified through simulation and working model.

7 References

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