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Design Of Novel Array Flexible Antenna With Enhancement In The Performance By Using Transparent Material

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Abstract – *This research simulates a new flexible antenna design using CST Software 2019. The innovative aspect introduced in this study involves placing a polyethylene substrate in front of the flexible antenna that was originally designed on a textile substrate. This addition serves the purpose of safeguarding the flexible antenna from environmental factors, especially during rainy conditions. When the antenna gets wet, it changes its properties and characteristics, primarily due to alterations in the dielectric constant. As a result, the polyethylene substrate is applied to prevent moisture absorption. The research presents simulation results, including data on return loss, radiation patterns, and axial ratio in both 2-D and 3-D formats. This research introduces an innovative design for a flexible antenna array intended for wireless applications. The antenna is simulated with CST software and is specifically aimed at creating a body area network operating at a single frequency band of 12.3 GHz. The substrate material for the antenna is denim jeans, with a dielectric constant of 1.7. It is covered with a layer of polyethylene substrate, which has a dielectric constant of 2.25 and incorporates a conductive element made from copper tape. The physical dimensions of the antenna board are 60x40 mm. The designed antenna offers a relatively wide bandwidth of 44.8%, spanning the frequency range from 12GHz to 12.55GHz, making it suitable for the intended purpose. This kind of bandwidth is considered optimal for this antenna. The proposed single-band antenna design is versatile and well-suited for use in multiband applications and wearable devices within wireless body area networks (WBANs). It's important to note that antennas featuring multiple identical patches are commonly referred to as array antennae.*

Key Words: Polyethylene substrate, Single band, Wearable antenna software.

1.INTRODUCTION

Both companies and researchers have been more interested in flexible technologies in the last several years. This research area has become a top priority for many public research agencies. As we develop flexible electronic systems, it's crucial to include antennas that can work within specific frequency ranges. This is because there's a high demand for wireless connectivity in our data-driven society today, and these antennas help make it all possible [1-4].

The performance of these systems primarily hinges on the quality of the integrated antenna. Flexible wireless technologies call for the inclusion of adaptable, lightweight, compact antennas with a low profile. At the same time, these antennas should be highly efficient, effective with reasonably broad bandwidth, and exhibit favorable radiation characteristics, as indicated in references [5-11].

In this research, a 2-diamond shape with a 2-L cut shape flexible antenna which is an array antenna designed on the material having a dielectric constant of 1.7 known as Jeans covered with polyethylene substrate that has a dielectric constant of 2.25 and saves the antenna from aging-related-losses.

1.1 Array Antenna

An array antenna that consists of two or more identical patches refers to a configuration where multiple antenna elements, typically of the same size and shape, are placed near form a collective antenna system. These identical patches work together to achieve specific radiation characteristics and beamforming capabilities. When multiple patches are used in an array, they can be individually controlled in terms of phase and amplitude to create desirable radiation patterns, such as steering the main lobe in a particular direction or improving signal reception and transmission in specific areas. The coordination and manipulation of these identical patches enable the array antenna to exhibit enhanced performance, directivity, and gain for various applications, including in wireless communication systems and radar systems.

1.2 Wearable Antenna

Antennas designed for wearing are commonly referred to as wearables. These wearable antennas find extensive use in applications like biomedical RF systems and wearable wireless communication. They are particularly valuable in wireless body area networks (WBANs), where an antenna plays a pivotal role in enabling wireless communication, encompassing off-body, on-body, and even in-body connectivity. Wearable antennas have a wide range of applications across diverse sectors, including health monitoring, entertainment, business, security, military defense, and many other fields [12]. Fig.1. illustrates wearable technologies and their uses. Wearable antennas are constructed from a variety of conductive as well as dielectric materials. Such materials are wisely selected to allow for reasonable mechanical deformations (such as twisting, wrapping, and bending) with minimal impact under various weather conditions (ice, snow, rain, etc.), while also providing effective electromagnetic radiation protection. More recently, alternative materials, both fabric and non-fabric, have been utilized in the development of wearable antennas. When using fabric materials, it is crucial to accurately characterize the properties of these textiles [13]. On the other hand, non-fabric flexible polymer-based materials like PET (Polyethylene terephthalate), Kapton, and PEN (Polyethylene naphthalate) substrates offer consistent and stable dielectric characteristics [14].

2. Dielectric Constant

Jeans Material: Denim, or jeans, has a dielectric constant of 1.7.

Polyethylene Material: Polyethylene has a dielectric constant of 2.25.

Table -1: Simulation of a 2 dimond shape with 2-L cut shape antenna.

This table represents the previous work and proposed work			
Sno.	Parameters.	Previous Work.	Proposed Work.
1.	Dielectric Permittivity.	1.7 (Jeans Material). 2.25 (Polyethylene substrate).	1.7 (Jeans Material) 2.25 (Polyethylene substrate)
2.	Ground (LgXBg) [mg].	61x17.5 mm.	60x40 mm.
3.	Length of the stripe line.	Not used.	50 mm.
4.	The breadth of the stripe line.	Not used.	2mm.
5.	Substrate Dimension.	61x51 mm.	40x45 mm.
6.	Substrate Thickness [mm].	1 mm.	1 mm.
7.	Resonant Frequency.	7.5 GHz.	12.3 GHz.
8.	The thickness of the ground.	0.0038.	0.0038.
9.	Loss Tangent.	0.0028 (Jeans Material)	0.0028 (Jeans Material) 0.0005 (Polyethylene substrate).

Resonant Frequencies: 12.3 GHz

Bandwidth Calculation: Single Band

F1 = 12 GHz

F2 = 12.55 GHz

Bandwidth = (F2 – F1) / [(F1 + F2)/2]

Bandwidth= 44.80%

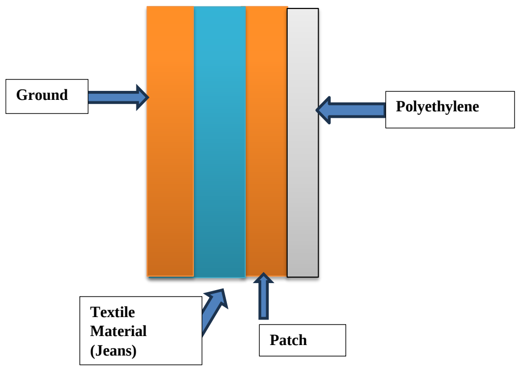

Figure -1:Layout of the antenna on textile material

The layout of the flexible antenna we've introduced is shielded with polyethylene. This serves the dual purpose of safeguarding the flexible antenna from moisture. Subsequently, a comparison of the results is conducted to readily discern the benefits of employing a polyethylene substrate.

3. Antenna Design Tactics.

A new concept was introduced for creating a flexible antenna enclosed in polyethylene and made using denim material. This innovative antenna features a ground size of 60x40 mm and operates at a resonance frequency of 12.3GHz. The overall outcomes have been enhanced and verified through design using CST (Computer Simulation Technology) software. Additionally, the antenna has been designed with a polyethylene covering to protect it from environmental factors like moisture and dirt. With the polyethylene cover, the antenna resonates at 12.3 GHz.

4. Comparison Between Previous Design And Proposed Design

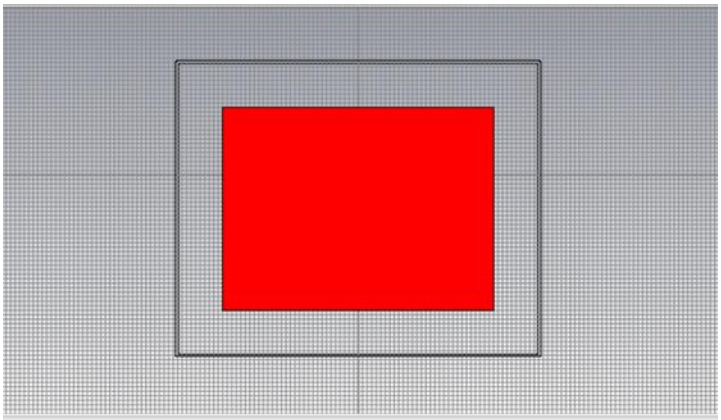

Figure-2: Front view of proposed design covered with polyethylene substrate (Dielectric constant=2.25).

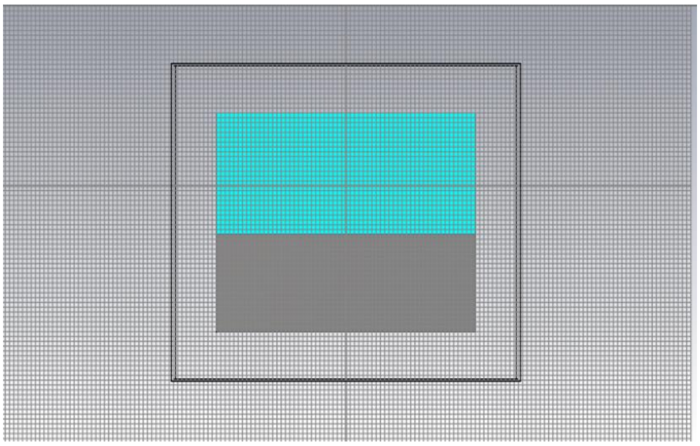

Figure-3: Reverse View of the proposed design.

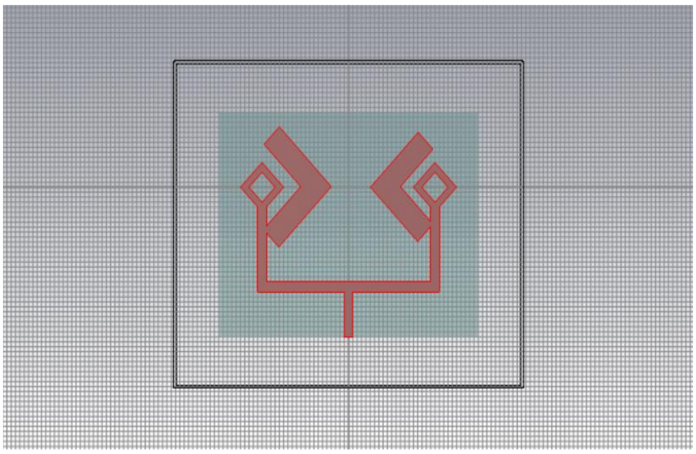

Figure-4: 2-diamond-shaped 2-cut antenna with dielectric constant=1.7 (Jeans Material)

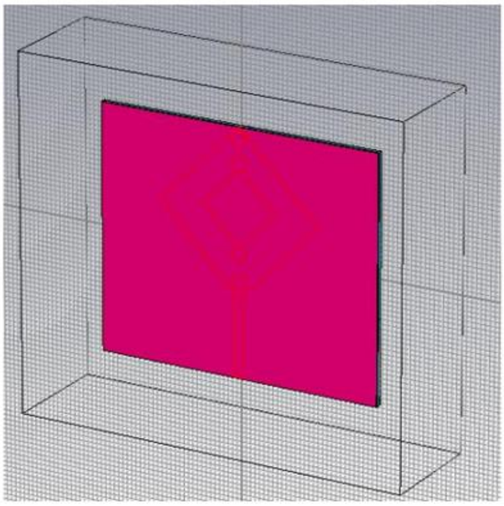

Figure-5: Previous Design with polyethylene substrate.

5. Result and Analysis

According to the research provided in this article, the flexible antenna on the front side of the antenna is shielded from water by a unique transparent substance called polyethylene. Polyethylene has a dielectric constant of 2.25. The three-dimensional perspective of a flexible polyethylene-covered antenna is shown in Figure 2.2. The different properties of polyethylene material are shown in Table 3.

S Parameter.

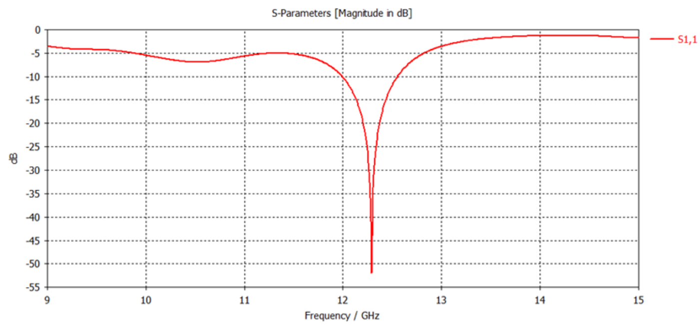

Figure-6: S Parameter.

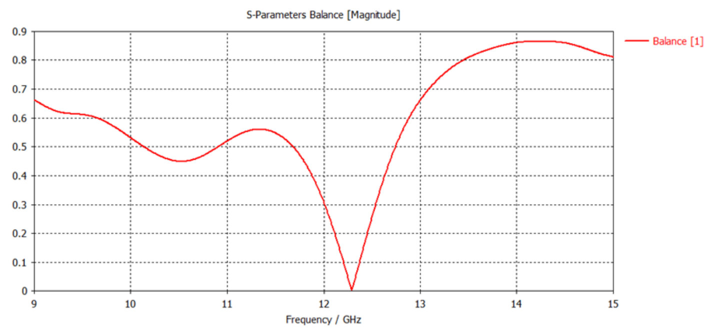

Figure-7: S Balance Parameter.

S Parameter- The S-parameter refers to how well a circuit can handle signals coming in and going out. It quantifies how much of the signal is reflected due to the mismatch between the circuit's input and the connected device's impedance.

Radiation Pattern.

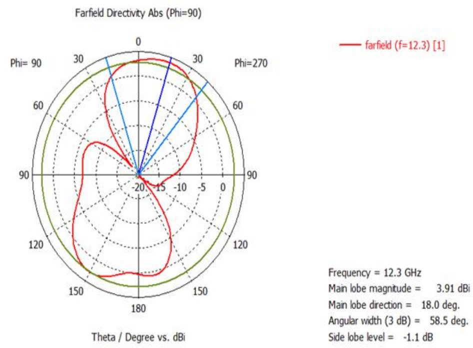

Figure-8: Polar Radiation Pattern at 12.3 GHz.

The suggested antenna provides a visual representation of its radiation pattern through a polar plot at the resonant frequency of 12.3GHz. Additionally, in Figure 9, we can observe the 2-D Cartesian radiation patterns at the same frequency. Furthermore, both Figure 10 and Figure 11 display the 2-D & 3-D radiation patterns at the antenna's resonant frequency of 12.3GHz. These radiation patterns reveal important characteristics, such as the main lobe's orientation at 18.0 degrees, an angular width of 58.5 degrees (3 dB), and a main lobe magnitude of 3.15 dBi at φ=90o. At this resonant frequency of 12.3GHz, the radiation efficacy is approximately 0.007867dB, while the directivity measures 3.004dBi.

Polar Radiation Pattern-An antenna's polar radiation pattern is a pictorial depiction of the ways in which it emits or receives electromagnetic energy in relation to its physical orientation. This pattern is typically displayed in a polar coordinate system with the antenna at the center. It illustrates how the antenna's performance varies with azimuth (horizontal) and elevation (vertical) angles. By examining the polar radiation pattern, one can understand the antenna's coverage, gain, and directivity, providing insights into its suitability for different applications. For example, a directional antenna will have a polar pattern that concentrates energy in a specific direction, while an omnidirectional antenna will have a more uniform distribution of energy in all directions.

Axial Ratio Polar Form-The axial ratio is referred to the ratio of the major axis to the minor axis of an antenna's circularly polarized radiation pattern. In other words, it quantifies how stretched or compressed the elliptical shape of the antenna's polarization pattern is, providing information about the deviation from perfect circular polarization.

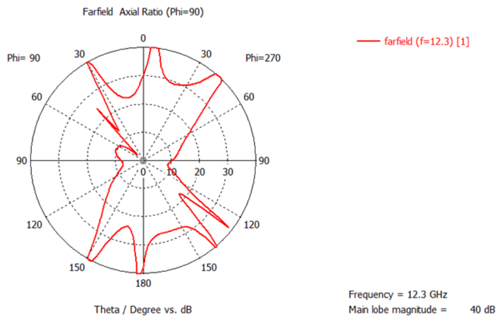

Figure-9: Axial Ratio Polar Form at 12.3 GHz.

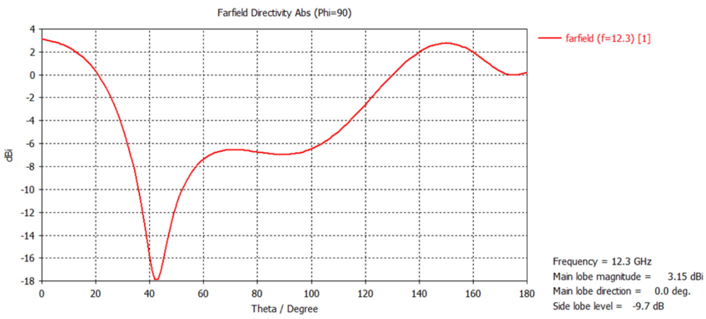

Figure-10: 2D Cartesian Radiation Pattern. 12.3 GHz.

2D Cartesian Radiation Pattern-A 2D Cartesian radiation pattern of an antenna is a pictorial depiction that displays how the antenna radiates or receives electromagnetic energy in a two-dimensional plane, usually the horizontal plane (azimuth). It provides a visual map of the antenna's performance, showing the strength and direction of radiation or reception at different azimuth angles, typically represented on a rectangular grid. This representation allows engineers and designers to assess the antenna's coverage and gain in the horizontal plane, providing essential insights into its directional characteristics without considering the vertical dimension.

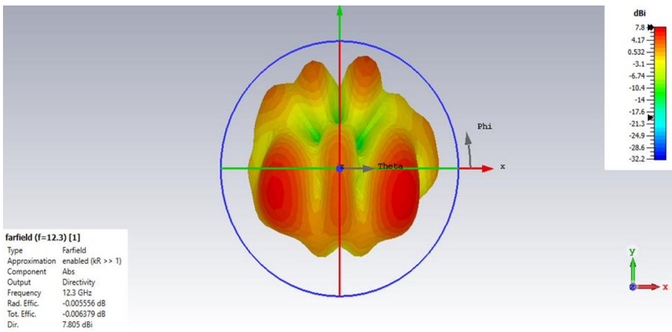

Figure-11: 3D Cartesian Radiation Pattern at 12.3 GHz.

3D Cartesian Radiation Pattern- The 3D Cartesian radiation pattern of an antenna is a pictorial depiction that illustrates how the antenna radiates or receives electromagnetic energy in three-dimensional space. It describes how the antenna's performance varies across different directions, not just in a flat plane. The pattern is typically presented as a three-dimensional plot, where the antenna's radiation propertiess are shown in terms of azimuth (horizontal direction), elevation (vertical direction), and radial distance from the antenna. This representation provides a comprehensive view of how the antenna's energy is distributed in all directions around it, offering valuable information for antenna design and analysis.

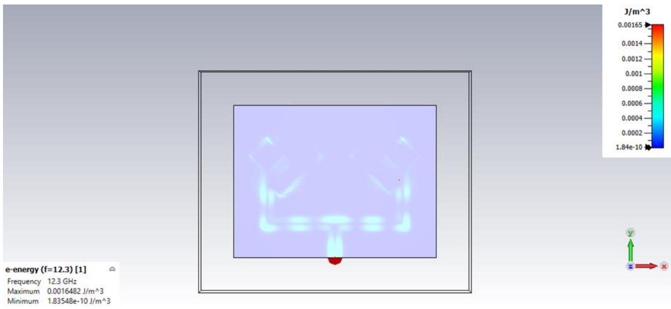

Figure-12: E-energy density at 12.3 GHz.

E-energy density: The E-field energy density of an antenna is a measure of the electromagnetic energy stored in the electric field surrounding the antenna. It quantifies the concentration of energy within the electric field components of the electromagnetic wave radiated or received by the antenna. This energy density provides insights into the distribution of energy within the electromagnetic field and can be useful for understanding the antenna's radiation characteristics and interactions with its surroundings.

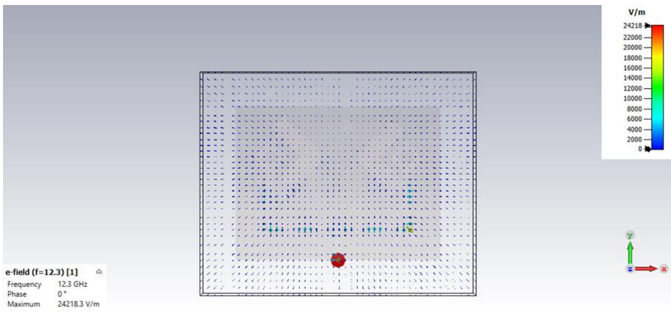

Figure-13: E-Field at 12.3 GHz.

E-Field: The E-field (electric field) of an antenna refers to the electric component of the electromagnetic field generated by the antenna when it radiates or receives signals. It represents the strength and direction of the electric field at various points in the space surrounding the antenna. The E-field, along with the H-field (magnetic field), constitutes the complete electromagnetic wave. Understanding the E-field is crucial for assessing the radiation properties of the antenna and how it interacts with other objects or antennas in its vicinity.

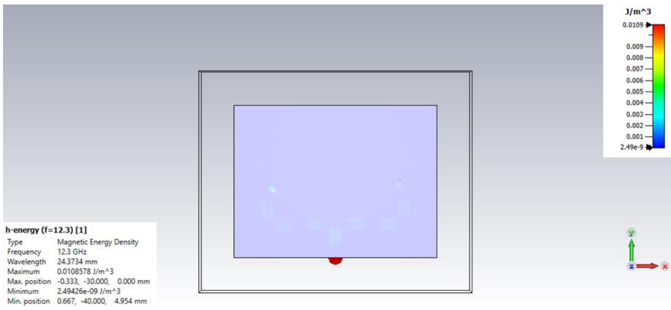

Figure-14:H energy density at 12.3 GHz.

H-energy density: The H-field energy density of an antenna is a measure of the electromagnetic energy stored in the magnetic field surrounding the antenna. It quantifies the concentration of energy within the magnetic field components of the electromagnetic wave radiated or received by the antenna. This energy density provides insights into the distribution of energy within the electromagnetic field and can be useful for understanding the antenna's radiation characteristics and interactions with its surroundings.

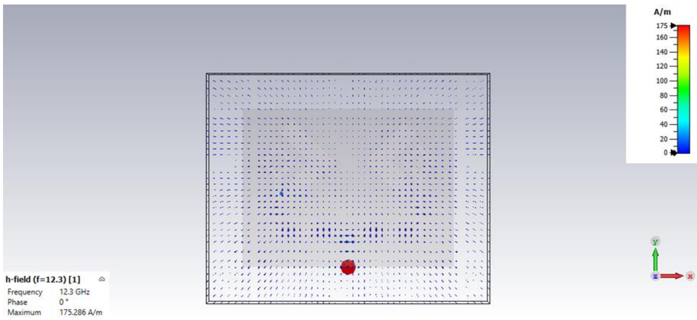

Figure-15: H field at 12.3 GHz.

H field: The H-field (magnetic field intensity) of an antenna refers to the magnetic component of the electromagnetic field produced by the antenna when it radiates or receives signals. It characterizes the strength and direction of the magnetic field at various points in the space surrounding the antenna.

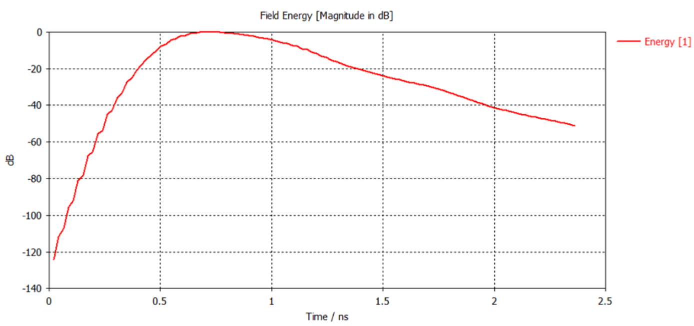

Figure-16: Excitation Energy.

Energy excitation of an antenna refers to the process of supplying electrical power to the antenna so that it can efficiently transmit or receive electromagnetic waves. This electrical energy is converted into electromagnetic radiation during transmission or into electrical signals during reception, enabling the antenna to perform its intended communication function. How the energy is applied to the antenna, including its frequency, voltage, and phase, can impact the antenna's performance and characteristics. on.

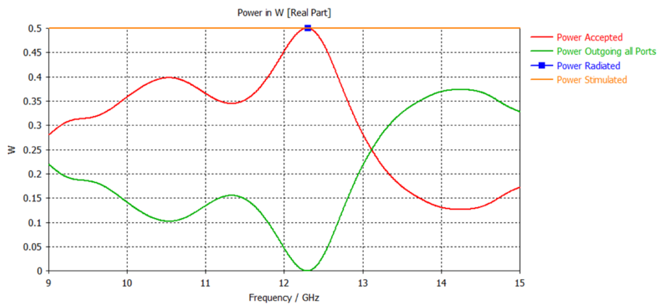

Figure-18: Power Excitation.

Power Excitation: Power excitation refers to the process of feeding or supplying electrical power to an antenna element. When an antenna is excited or fed with power, it generates electromagnetic waves that radiate into space to transmit or receive signals.

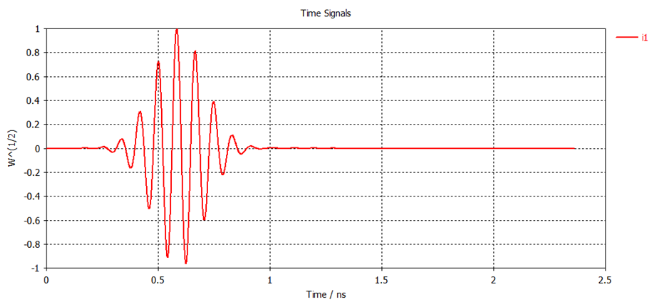

Figure-19: Port Signal.

Port Signal: A port signal in an antenna refers to the electrical or electromagnetic signal that is either transmitted into the antenna for broadcasting or received from the antenna for further processing.

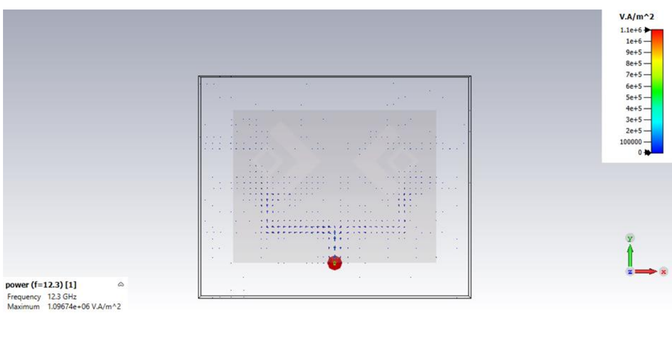

Figure-20: Power Flow.

Power flow: The power flow of an antenna refers to the transfer and distribution of electromagnetic energy. In transmitting antennas, it describes how electrical power is converted into electromagnetic radiation that propagates into space. Receiving antennas characterize the process of capturing electromagnetic waves from the environment and converting them into electrical signals. Understanding the power flow is essential for assessing the performance and efficiency of an antenna.

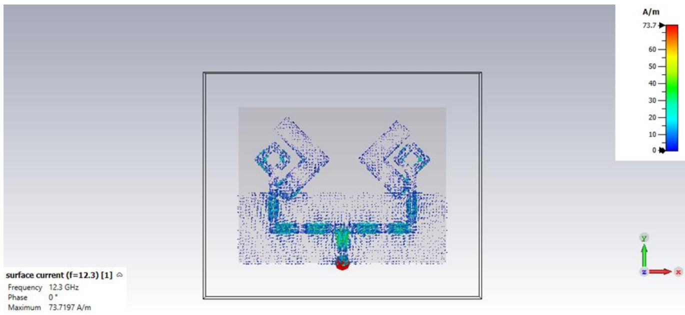

Figure-21: Surface Current at 12.3 GHz.

Surface current: Surface current in an antenna refers to the flow of electric current along the conductive surface of the antenna structure.

6. Application Of Wearable Antenna.

Figure-22: Various Applications Of Wearable Antenna.

7. CONCLUSIONS

The research paper's key contribution is its innovative approach to shielding the antenna from the adverse effects of environmental dangers. In this study, a novel array antenna has been studied which works on 12.3GHz resonant frequency. A 2-diamond shape 2-L cut antenna is designed in CST software in which its characteristics are improved by using jeans substrate which has a dielectric constant of 1.7 and it is covered with polyethylene substrate which helps in protecting the antenna from wear and tear losses. If an individual wearing this antenna gets wet, it causes the antenna's characteristics to alter, consequently impacting its radiation pattern to address this issue, a flexible antenna has been designed on a textile material with the same dielectric constant. The only modification is that the antenna is now shielded with a polyethylene substrate. The antenna is used for single band antenna with an improved bandwidth of 44.80% for frequency range (12-12.55) GHz and the overall directivity is also increased which is better for communication applications. This antenna offers protection against environmental factors such as rain, which can make it wet and heavy. When it becomes wet, the change in its dielectric constant alters its properties, subsequently affecting the antenna's overall performance. Importantly, this antenna is well-suited for Internet of Things (IoT) applications.

FUTURE SCOPE

Recently the frequencies used for 5G mobile communication is about 1 to 6 GHz. In our research we have used frequency that is beyond 10 GHz, 12.3GHz and its bandwidth is around 44.80%. In the future, this type of frequency can be used for and can be worked for 6G and 7G applications.

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