A FLEXIBLE ECE-SHAPED HIGH GAIN ANTENNA ARRAY FOR WEARABLE APPLICATIONS

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ABSTRACT

Wearable antennas are designed to function to be worn. These antennas are commonly used in wearable wireless communication. The three-element flexible array antenna is designed with ECE-Shaped slots by using flexible felt material as substrate with a thickness of 3mm, and its permittivity is 1.22 to give good insulation. This array antenna is designed for a frequency of 2.4 GHz with dimensions of 173 mm by 50 mm, and the distance between patches is chosen to be 20 mm. The return loss is at S11 = -15 dB. This design can cover the ISM band and provide good performance. The parameters that are listed from the designed antenna are the reflection coefficient, VSWR, gain, directivity, and specific absorption rate (SAR), which should be less than safety levels. The designed three-element flexible array antenna is applicable for biomedical applications.

Keywords: felt material, flexible, wearable device, reflection coefficient (S11).

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1. INTRODUCTION

Biomedical mention to the field of study and the applications of principles and techniques of engineering, biology, and medicine to solve problems related to human health and disease. The paper proposes the use of a circularly polarized patch antenna array for the detection of kidney cancer. The proposed antenna array is designed to operate at a frequency of 2.45 GHz, which is the resonant frequency of water molecules. The paper discusses the design of the antenna array and the simulation results obtained using CST Microwave Studio from [1]. Biomedical research is focused on understanding the underlying mechanisms of diseases, developing new diagnostic tools and treatments, and improving the overall quality of life for patients. Examples of biomedical research and applications include the development of artificial organs, such as artificial hearts and kidneys, the design of prosthetics and assistive devices for individuals with disabilities, and the creation of vaccines and therapies for infectious diseases and chronic illnesses such as cancer and diabetes.

To design and optimize wearable antennas, electromagnetic simulation software such as HFSS or CST can be used. These tools allow engineers to simulate the antenna's performance and optimize its design parameters such as its dimensions, material, and shape to achieve desired performance characteristics. Overall, wearable antennas play a crucial role in enabling wireless communication in a variety of wearable applications, and continued research and development in this area is essential for the advancement of wearable technology.

Figure-1. Wearable technology.

It involves the use of Wearable technology shown in Figure-1, engineering, and science to develop new therapies, devices, and diagnostic tools to improve human health and well-being. The use of electromagnetic waves for the detection of cancer. The use of antenna arrays for detecting cancer cells. The use of a specific absorption rate (SAR) technique to analyze the dielectric properties of cancerous tissues. The potential of microwave sensors and antenna arrays for early detection of cancer. The focus is on the detection of specific types of cancer, such as breast cancer, brain cancer, and kidney cancer. The simulation results presented in the papers demonstrate the effectiveness of the proposed techniques. The importance of early detection in improving the prognosis and survival rates of cancer patients from [1]-[5]. Biomedical research encompasses a wide range of areas, including basic research in biology, genetics, and biochemistry, as well as clinical research in fields such as oncology, neurology, cardiology, and immunology [8]-[9]. Biomedical research also includes the study of public health and epidemiology, which focuses on the prevention and control of diseases [9].

2. ANTENNA DESIGN

Design Equations

An initial guess at the patch width:

$$W = \frac{c_o}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}, \; c_o \text{ is the speed of light} \qquad [1]$$

Find effective parameters:

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}, W/h > 1 \qquad [2]$$

$$\frac{\Delta L}{h} = 0.412\frac{\left(\epsilon_{reff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\epsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)} \qquad [3]$$

Get patch length:

$$L = \frac{c_o}{2f_{r\sqrt{\epsilon_{reff}}}} - 2\Delta L \qquad [4]$$

Where fr is the frequency at which it operates, E_r and h are the constants for the dielectric and altitude of the base, W and L are the width and length of the antenna, and f_o is the resonant frequency of the antenna.

The constant of dielectric is identified by E_{eff}. L_{eff} is the patch's effective length. The radiation covered the entire patch's breadth. We must determine the patch's width.

L_{sub} = 6h+L W_{sub} =6h+L

Here L_{sub} , and W_{sub} are the length and width of the base.

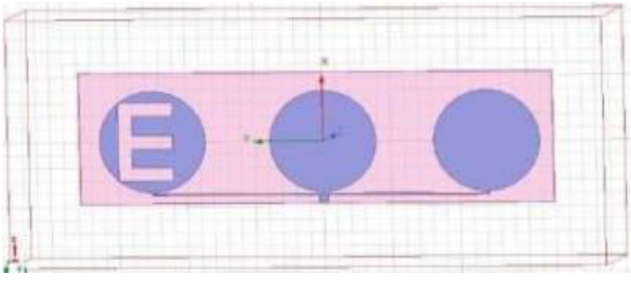

Figure-2. Antenna1 E-Shaped slot 1*3 array antenna.

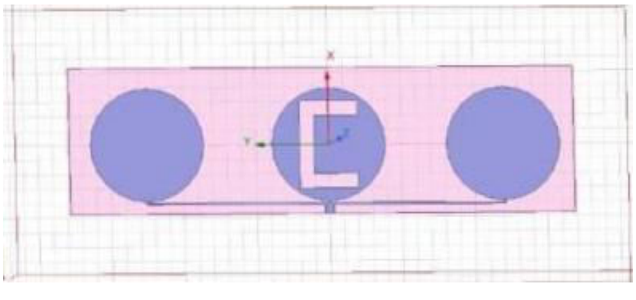

Figure-3. Antenna2 C-Shaped slot 1*3 array antenna.

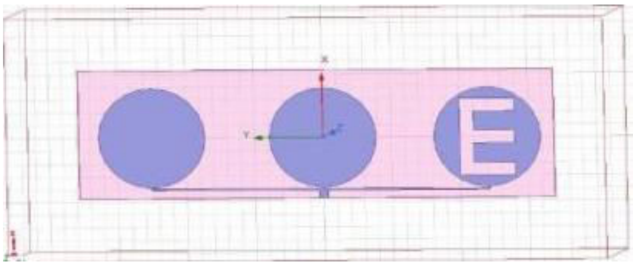

Figure-4. Antenna3 E-Shaped slot 1*3 array antenna.

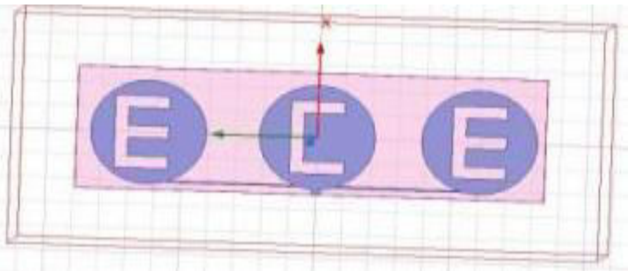

Figure-5. Antenna4 proposed antenna ECE-shaped slot 1*3 array antenna.

The iterations of the proposed antenna include four cases where in Fig [5] the antenna consisting of ECE shaped slot 1*3 array antenna where its return losses is about -15dB and its VSWR is 0.5 at 2.46GHz operating frequency which gives an efficient antenna measurements. From Figure [2] the antenna consists of E shaped slot 1*3 array antenna where its return loss is about -11.25dB and its VSWR is 1.75 at 2.15GHz operating frequency. From Fig [3] the antenna consists of C shaped slot 1*3 array antenna where its return losses is about -15dB and its VSWR is 0.1 at 1.75GHz operating frequency. From Fig [4] the antenna consisting of E shaped slot 1*3 array antenna where its return loss is about -10.5dB and its VSWR is 1 at 3.9GHz operating frequency is obtained.

3. PROPOSED ANTENNA

A circularly arranged antenna system is made up of three separate antenna components. There are two types of circular arrangements co co-planar, in which all the components are in the same plane, and non-coplanar, in which the elements are at various heights above the ground. The three-element circular array antenna's directed radiation pattern and circular polarization are intended to be produced. The antenna may guide the primary lobe of its radiation pattern in a particular direction while suppressing emission in other directions by adjusting the phase and amplitude of the signals sent to each element. When circular polarization is necessary, as in radio astronomy, GPS, and satellite communications, circular arrays are frequently utilized. In comparison, they can also offer more bandwidth and better impedance matching.

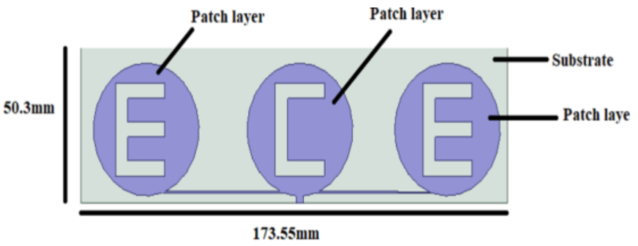

Figure-6. Top view of the proposed antenna array and feeding network.

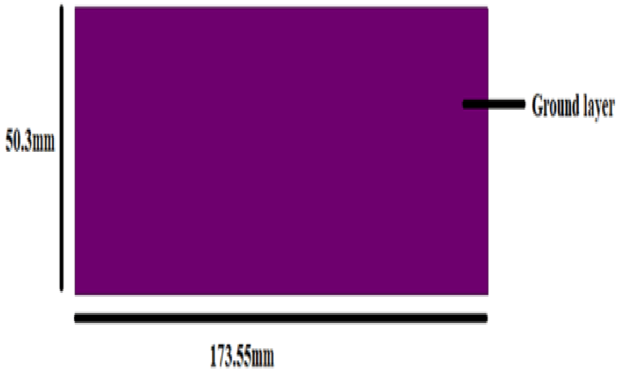

Figure-7. Back view of the proposed antenna array.

Table-1. Proposed antenna characteristics.

Characteristic	Parameters
Base Material	Felt
Permittivity[ε]	1.22
Thickness	3mm
Width	50mm

3.1 Proposed Antenna Simulation Results

The reflection coefficient of a 3-element array of components, the distance between them, and the operating frequency may all be used to compute the input impedance of a 3-element array antenna. The feed line generally has a characteristic impedance of 50 or 75 ohms. A three-element array antenna's voltage standing wave ratio (VSWR) is influenced by the reflection coefficient, which is in turn affected by the antenna's input impedance and the transmission line's characteristic impedance. The VSWR, which is commonly defined as the ratio of the highest voltage to the minimum voltage along the transmission line, is a measurement of how well the antenna can transmit energy from the transmission line to the antenna components.

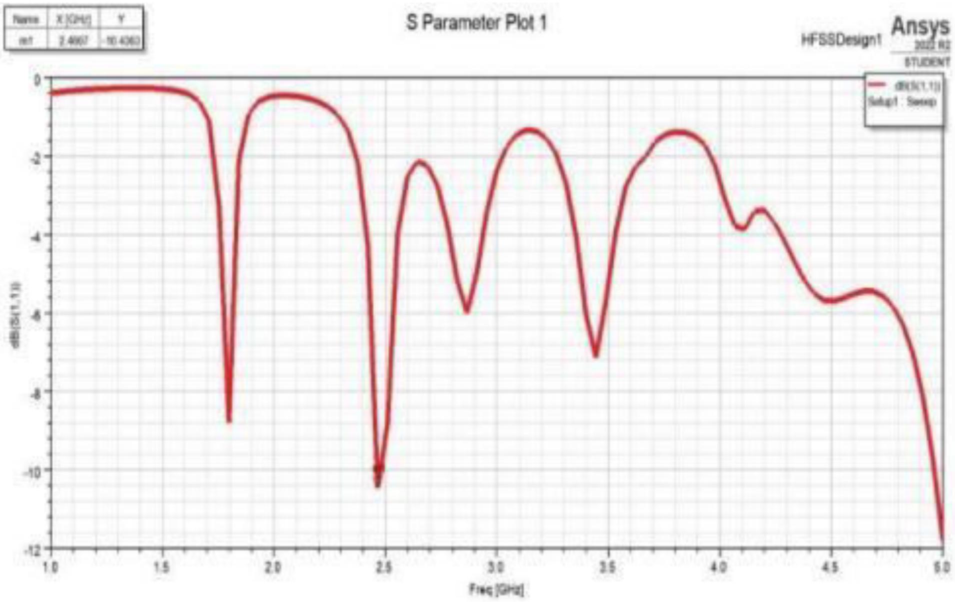

Figure-8. The antenna-4 proposed antenna S11.

The impedance of the feed line, the frequency of operation, the design of the antenna, and any impedance matching network used, if any, all have an impact on the reflection coefficient of a 3-element array of components, the distance between them, and the operating frequency may all be used to compute the input impedance of a 3-element array antenna. The feed line generally has a characteristic impedance of 50 or 75 ohms. A three-element array antenna's voltage standing wave ratio (VSWR) is influenced by the reflection coefficient, which is in turn affected by the antenna's input impedance and the transmission line's characteristic impedance. The VSWR, which is commonly defined as the ratio of the highest voltage to the minimum voltage along the transmission line, is a measurement of how well the antenna can transmit energy from the transmission line to the antenna components.

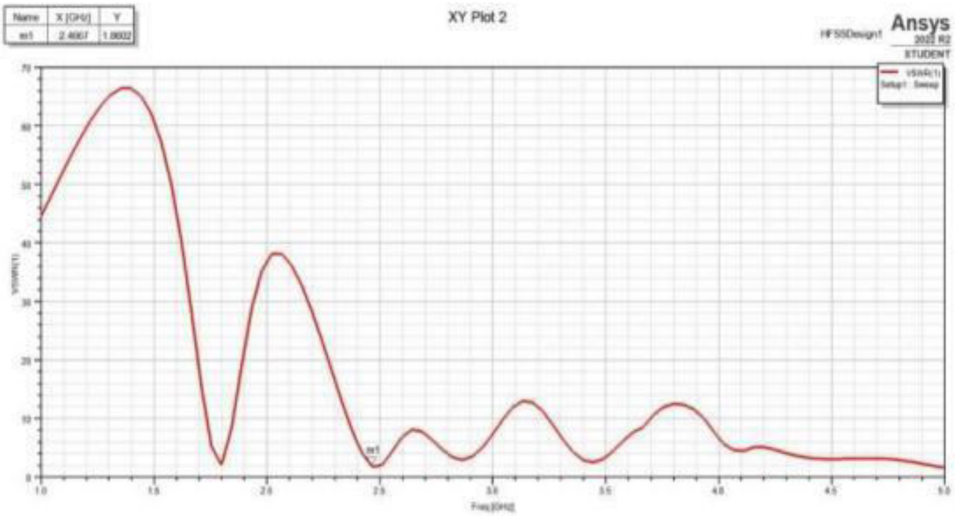

Figure-9. The antenna-4 proposed antenna VSWR.

3.2 Measurement for Proposed Antenna

After the simulation of the designed proposed antenna, this model was sent to fabrication to test and measure the results. In Figure-10 and Figure-11 Top and Back views of the Proposed Fabricated antenna with feed element representation.

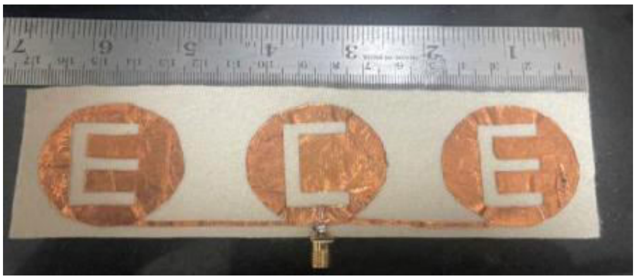

Figure-10. Top view of the proposed antenna-4 array.

Figure-11. Bottom view of the proposed antenna-4 array.

3.2.1 Free space measurement and off -body measurement

The fabricated antenna is tested by a Vector Network analyzer and the S11 at free space and off body are shown in Figure-12 and Figure-13.

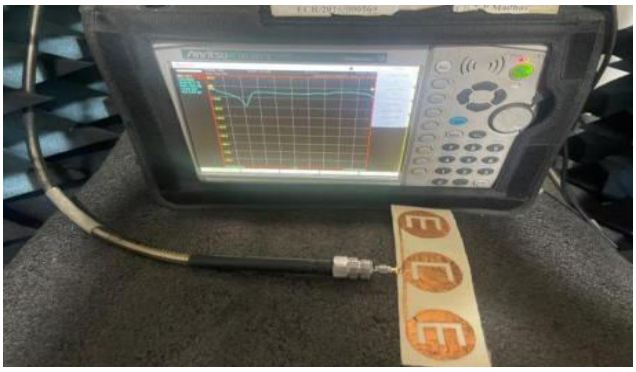

Figure-12. The antenna-4 proposed antenna S11 at free space.

Figure-13. The antenna-4 proposed antenna S11 on the human body.

When an antenna is on the body surface, due to bends being presented on the human body, the result can also change. The radiation pattern is how the antenna emits or receives signals in different directions. The presence of the body or other objects can cause the radiation pattern to become distorted, which can affect the range and accuracy of the maximum bending stress evaluated and compared to the allowable stress for the material. If the maximum bending stress exceeds the allowable stress, the material may fail. The deflection of the material or structure is calculated using the bending moment, section properties, and material properties. Bending analysis is important in many engineering applications, including the design of beams, columns, and other structural components.

4. COMPARISON OF SIMULATION RESULTS

From Figure-14 the S11 parameters for all four cases, Figure-2, Figure-3 Figure-4, and Figure-5 are obtained, S11 for the Figure-8 proposed antenna is observed below -10dB.

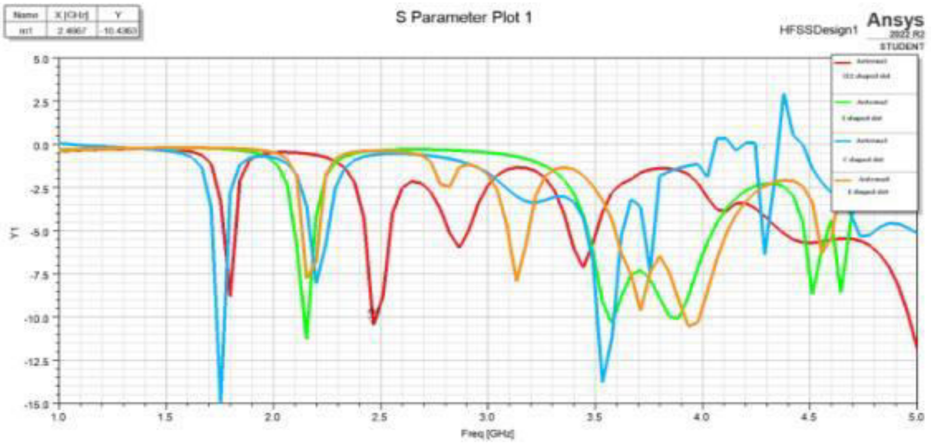

Figure-14. Result of S11 for Antenna-1, Antenna-2, Antenna -3 and Antenna-4 proposed antenna.

From Figure-15 the Voltage Standing Wave Ratio (VSWR) for all four cases, Figure-2, Figure-3 Figure-4, and Figure-5 are obtained, and VSWR for the Figure-6 proposed antenna is observed.

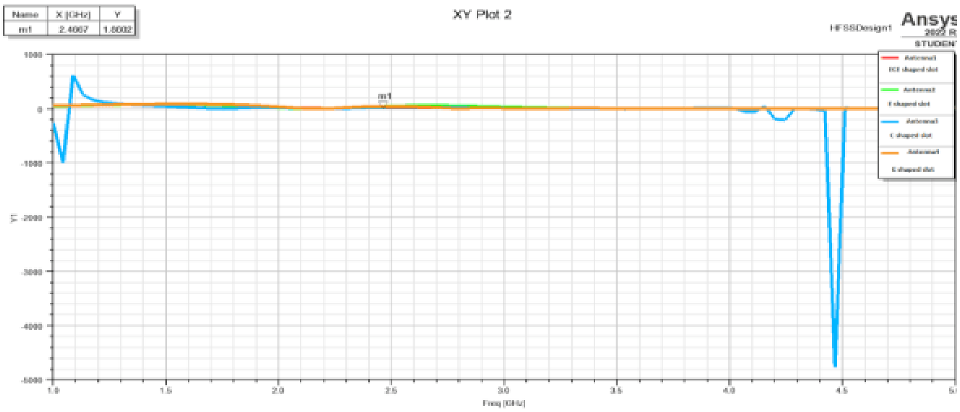

Figure-15. Result of VSWR for Antenna-1, Antenna-2, Antenna -3 and Antenna-4 proposed antenna.

From Figure-16 the Gain characteristics for all four cases, Figure-2, Figure-3, Figure-4, and Figure-5 are obtained, and the Gain characteristics for the Figure-6 proposed antenna are observed.

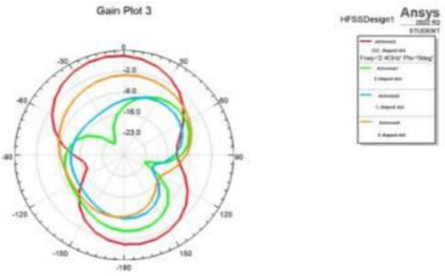

Figure-16. Radiation pattern for Antenna-1, Antenna-2, Antenna -3 and Antenna-4 proposed antenna.

S11 is a measure of how much of the electromagnetic energy sent to an antenna is reflected. It is also called the reflection coefficient or return loss. S11 is usually measured in decibels (dB), and a lower S11 value indicates better antenna performance. VSWR, or voltage standing wave ratio, is another measure of antenna performance that is closely related to S11. VSWR is the ratio of the maximum voltage to the minimum voltage on the transmission line connected to the antenna. A lower VSWR indicates better antenna performance. Radiation pattern refers to the directional characteristics of an antenna's radiation in space. It describes how the antenna radiates energy in different directions. The radiation pattern is typically represented graphically, with a polar plot showing the antenna's gain (the amount of energy radiated in a particular direction) as a function of the angle relative to the antenna's axis. Merging radiation patterns involves combining the radiation patterns of multiple antennas to form a composite pattern. This can be useful in situations where multiple antennas are used in an array or other configurations, such as diversity antennas used in wireless communication systems.

Table-2. Comparison table for all iterations.

S. No	Designs	Operating Frequency	S11 IN dB	VSWR	3dB GAIN	3dB Directivity
1	1*3 Array with Felt material with slot E (Figure-1)	2.15	-11.25	1.75	2.81	3.38
2	1*3 Array with Felt material with slot C (figure-2)	1.75	-15	0.1	-2.85	4.26
3	1*3 Array with Felt material with slot E (Figure-3)	3.9	-10.5	1.0	0.06	4.26
4	1*3 Array with Felt material with slot ECE (figure 4 or 8)	2.46	-15	0.5	3.42	9.37

5. CONCLUSIONS

The proposed antenna exhibits an array structure to achieve an improvement in its performance in terms of its Return loss, VSWR, Gain, and Radiation pattern. Further, the simulation results show that the proposed array antenna has improved parameters like return loss and gain with -15dB and 3.42dB respectively. The results of this study show that the proposed antenna is used for biomedical applications.

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