Piezoelectric Driven Antenna System for Health Monitoring Gadgets

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Abstract— **Advancement in medical science is emerging day by day, and application of engineering technology in the field of medical science plays a very important role. In this paper, a novel method to monitor the health condition of an individual is developed. The proposed system uses piezoelectric devices to operate a health monitoring gadget with antenna that is suitable to operate for the piezoelectric based power source. The present day health monitoring gadgets require battery replacement or need to be charged. These would be a problem for the user when the device runs out of the charge. In order to overcome these challenges, the concept of piezoelectricity is applied to charge the gadget. The gadget consists of a transmitter, which is a wearable device, which will be worn by the patient, whose health condition has to be monitored. The receiver unit is placed in the nearest hospital, which will receive the physical conditions of the patient and, monitoring of the health condition is done. Piezoelectric based charging system is used to drive the proposed gadget. The transmission and reception is accomplished by GSM. In order to achieve better performance, microstrip antenna is used for transmission and reception. The simulation of the proposed system is done using Multisim, and simulation results are presented. The piezoelectric simulation is done using MATLAB and also the simulation of micro strip antenna is presented. Here the microstrip antennas will be stimulated for frequency range of 2-3 GHz and 5-6 GHz (preferably 2.2 and 2.5 GHz), using HFSS and MATLAB. The piezoelectric beam is simulated and the voltage produced for the deflection is noted. It was found that for deflection of 33um, a voltage of 100V is produced.The various performance parameters of the antenna, such as impedance, VSWR, reflection coefficient, return loss are obtained and presented.**

Keyword- Piezoelectric, GSM, Microstrip antenna, Radiation pattern.

I. INTRODUCTION

The antennas have been used in many fields according to their application. Antennas were developed for transmitting and receiving the message signal. As the requirement of antennas was seemed necessary in fields like defense, the application varied from using for communication to detecting objects. Humans have used antenna for communication since 100 years. Wireless communication had many drawbacks such as adding noise with transmitted signal, security issues, loss of messages etc. When the digital systems were used the technological advancement created made wireless communication cheap and reliable. The developments in digital systems lead to a revolution in antenna technology. The huge antennas can be used to transmit or receive more amounts of signals [1]. But it was difficult to reconfigure them. To enhance the efficiency of antennas the reflector and array antenna concepts were used [1]. The reflectors which created a revolutionary change in the field of optics when combined with arrays gives the solution for most of the issues faced in the advancement of antenna technology. The large antennas were replaced by a set of small antennas which can be reconfigured quite easily. Some of the features of array antenna and reflectors are adaptive beam forming, aperture distributed, potential for low RADAR cross section, wide bandwidth etc. Many antennas such as Reconfigurable sensing antennas which pushes the limits of conventional antennas which can only be used for transmitting and receiving signals by making it to sense the environment[2]. The reconfigurable sensing antenna which can sense the environment uses the physical sensors as the other antennas use devices such as diode to control them. The most promising reconfigurable sensing antenna consists of integrated chip, physical sensor and antenna structure. The weight of antenna is very critical in space applications [3]. The solar powered satellite uses the solar energy for its working. The micro strip antennas are fit for such applications. Studies have proved that we can increase the gain of single element antenna by 14.3 dB by making use of arrays for a frequency of 5.8GHz [3]. The antenna field has developed rapidly from huge antennas to wearable antennas. The wearable antennas are made up of polymer substrate which is flexible and elastic [4]. Antennas which are built using polymer substrate such as Polydimethyylsiloxane. The gain of the Polydemethylsiloxane made antenna varies with frequency and maximum is observed as 4.65dB at 6.5GHz [4].

Micro strip antenna is widely used in many fields due to its various advantages like light weight, low profile because of this reason it is used in aero plane and space applications. Micro strip antennas are one of the most successful antenna ever invented it works in the frequency range 1GHz to 100 GHz [5]. Micro strip was developed in 1950's, till today it dominates the antenna applications. The developments in the below mentioned area has developed the antennas far beyond its conventional role [5]

- Recent developments in Meta materials.
- Wearable antennas.
- Applications in the medical field.
- Nano antennas.
- Reflectors and array developments.
- MIMO based applications.
- RFID antennas.

Microstrip antenna can have different shapes which suits its application. The widely used geometries are triangular, ellipse, rectangular ring etc [6]. In this paper we present the design of microstrip antenna, we analyze the results such as radiation pattern etc. Ansoft high frequency structural simulator software and MATLAB has been used for the purpose of analysis.

The term wearable antenna means an antenna suitable to wear. The tasks that can be concluded to be done by a wearable antenna is performing some tasks directly related to telecommunications like tracking and navigating, tasks relating to public safety, remote computing and communication tasks[7]. Wearable antenna technology has attracted many researchers working in this field especially for the application of wireless body area network which is used in body health care [4].The wearable antennas have now found application in the field of medical science. The wearable antennas has multiple features like low power consumption, high data transmission rate etc [4]. In recent years, body-centric wireless communication becomes an important part of fourth generation mobile communication systems (4G) [8]. Body-centric communications takes place firmly within the sphere of personal area networks (PANs) and body area networks (BANs). One of the applications – the on-body communications – describe the link between body mounted devices communicating wirelessly, while off-body communication defines the radio link between body worn devices and base units or mobile devices located in surrounding environment. Finally, in-body communication is communication between wireless medical implants and on body nodes [9].

Our design of wearable antenna uses a novel method of using piezoelectric effect in the system and then the health of the user is monitored and the results of which can be sent to the doctor who can analyse this result and can instantly send a prescription of medicines or in case an emergency can immediately visit the patient.

II. DESIGN OVERVIEW

The piezoelectric driven health monitoring device is a gadget used to monitor heart rate and transmit it to a nearby health centre. It runs using a piezoelectric crystal. Fig. 1 and fig. 2 shows the basic over view of the health monitoring device.

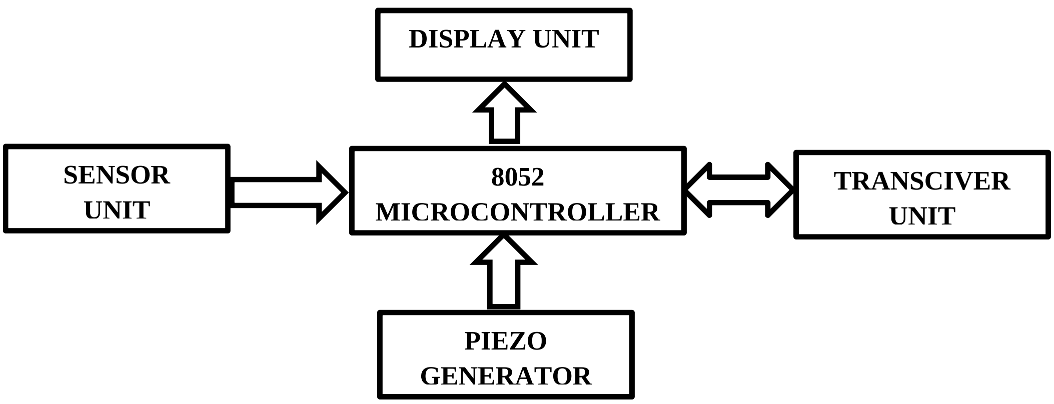

Fig. 1. Overview of Wearable Unit

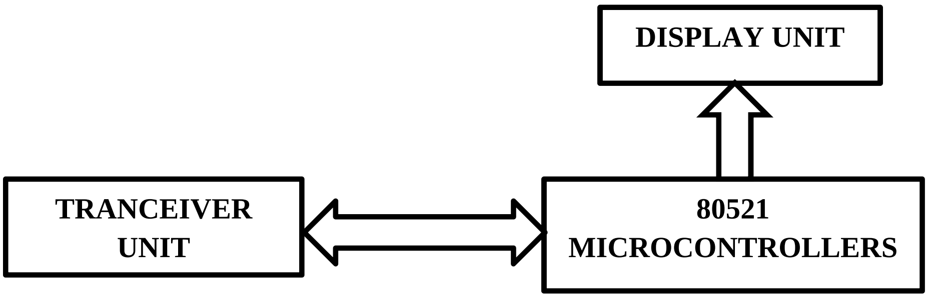

Fig. 2. Remote Monitoring Unit

The model consists of two units. One is the wearable unit which will be worn by the person to be monitored and the second unit is the one which will be placed in the health centre which is monitoring the person

A. Wearable Device

The wearable unit is worn by the person who is to be monitored. This device monitors the heart rate through sensor. The sensor output is given to a microcontroller. The microcontroller process the sensor input and sends it to a nearby health Centre through a transceiver.

1) *Sensor Unit:* The sensor unit detects the heartbeat. It consists of a combination of LED and photodiode as the basic sensing element. The emitted light of the LED will be reflected back to the photodiode. The intensity of the reflected light depends on the blood flow. The blood flow changes according to the heartbeat which in turn changes the light intensity. As the heartbeat rate increases, the change of intensity increases and it decreases when the heart beat decreases. This variation is converted to voltage variation by the photodiode. Thus varying amplitude pulse will be the output of the sensor. The frequency of the pulse determines the heart rate. The pulse frequency will be calibrated to a standard value and maximum and minimum threshold will be set.

2) *Microcontroller:* The microcontroller is an intermediate to all the other units. The microcontroller takes the reading from the sensor and based on standard limits it sets threshold voltages. The threshold is based on the frequency of the pulse. A maximum and minimum threshold will be set. If the maximum threshold is exceeded or frequency is decreased beyond minimum threshold an immediate alert will be sent. The reading will be transmitted only when required in order to conserve power or whenever the user wishes. Along with it the microcontroller controls a display unit which is used for displaying.

3) *Transceiver:* The transceiver unit is used for wireless communication between the wearable device and the remote monitoring centre. It sends the monitored signal to the required health centre. The transceiver also receives the signal which contains the recommended prescription. A GSM model could be used for long distance communication.

4) *LCD Display:* Liquid crystal display or LCD is very useful in providing user interface. It can be also used for debugging purposes. The LCD's are gaining more popularity and replacing LEDs. The LCD display is used for displaying.

5) *Piezoelectric Generator:* The device is powered by a piezoelectric generator. A PZT ceramic crystal generator can be used because of its higher efficiency. The generator powers up by the users motion [10].

B. Remote Monitoring Unit

The data send from the wearable health monitoring system will be received in a health centre by remote monitoring unit. This device consists of a transceiver, microcontroller and an LCD display. The transceiver receives patience pulse signal. It is processed by the microcontroller and is displayed in the LCD display. The doctor will analyse it and sends back the required prescription.

1) *Transceiver:* The purpose of the transceiver is to send and receive data. The transceiver receives pulse signal. This will be sent to the microcontroller to analyse. The required prescription will be sent back to the transceiver. The transceiver sends this data to the patient in a remote location.

2) *Microcontroller:* The received data is sent to the microcontroller. The microcontroller processes this data and displays it. The doctor analyses this data and sends it to the microcontroller. The microcontroller will send back the prescription to the transceiver to send it back to the patient.

3) *LCD Display*: LCD Display is used for displaying the physical parameters

III. SYSTEM IMPLEMENTATION

The system design includes the design of an wearable device, and an moniitoring device. Wearable device will be worn by the patient, whose health has to be monitored. The wearable device worn by the user has an inbuilt sensor that senses the heartbeat rate. This reading is transmitted to the destined health centre, with the help of transmitter designed using 8052 microcontroller and an GSM module, with proposed antenna. In this paper the transmission and reception of the signal is simulated using NI multisim software. The microcontroller is also connected to the LCD display, to keep track on the health condition. The Tx and Rx port of the microcontroller are connected to virtual terminal via serial ports P2B0RxD and P2B1TxD, for the purpose of simulation. The physical conditions such as heart rate are transmitted to the nearest health centre at the rate of 12kbps. The data is transmitted by serial communication in mode 1 where a start bit is sent first followed by 8 bit character and ended with a stop bit. The Circuit implementation is done using Multisim and is shown in fig.3.

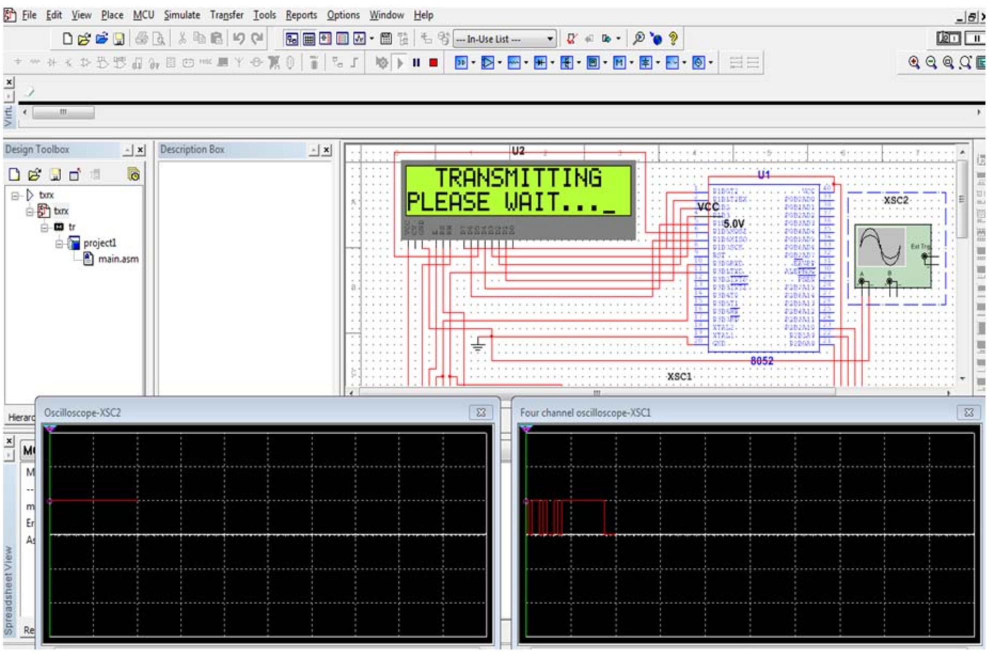

Fig. 3. Circuit Simulation using Multisim

The transmission and receiving is done through tx and rx port of the microcontroller. The transmission and the received signal are shown in the multisim using an oscilloscope. The oscilloscope xsc1 shows the transmission of data and oscilloscope xsc2 shows the received data. While transmitting, the data will be sent in pulses. the transmission is shown in fig 5.The xsc1 shows the transmission of data. In fig 4, there is no reading in oscilloscope xsc2. This is because the the received data will be stored in Serial Buffer Register(SBUF register) until all the values are received. The received data is shown in fig 4. The oscilloscope xsc2 shows the received signal. Only after all the bits are transmitted, it will be shown in the receiver. The LCD display is used for displaying.

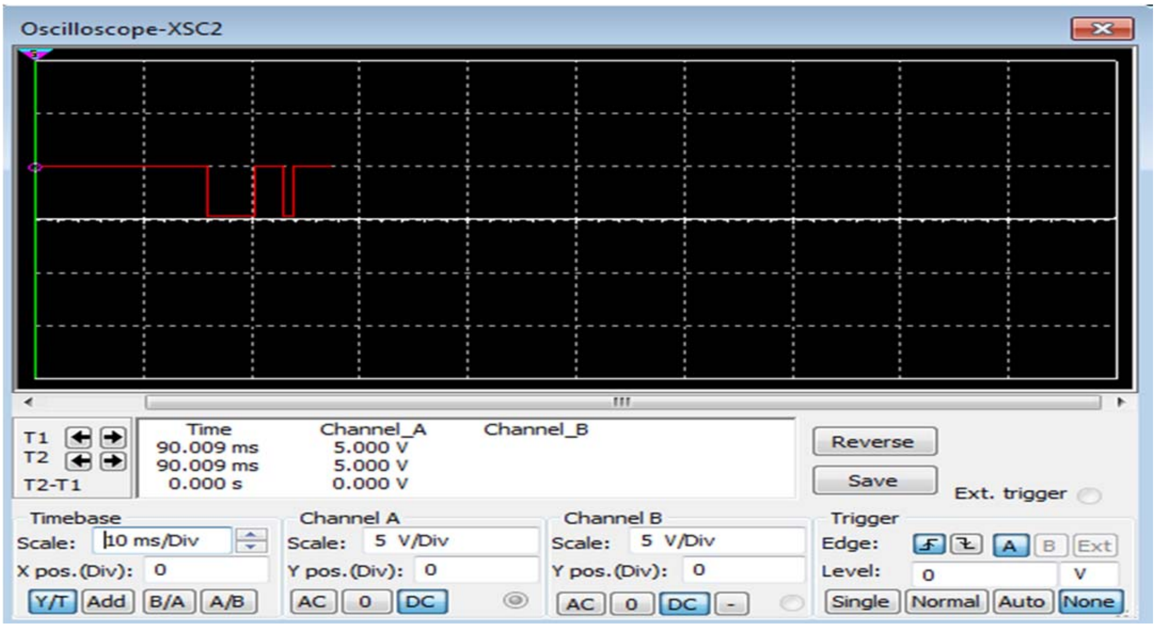

Fig. 4. Data Reception by the health Centre

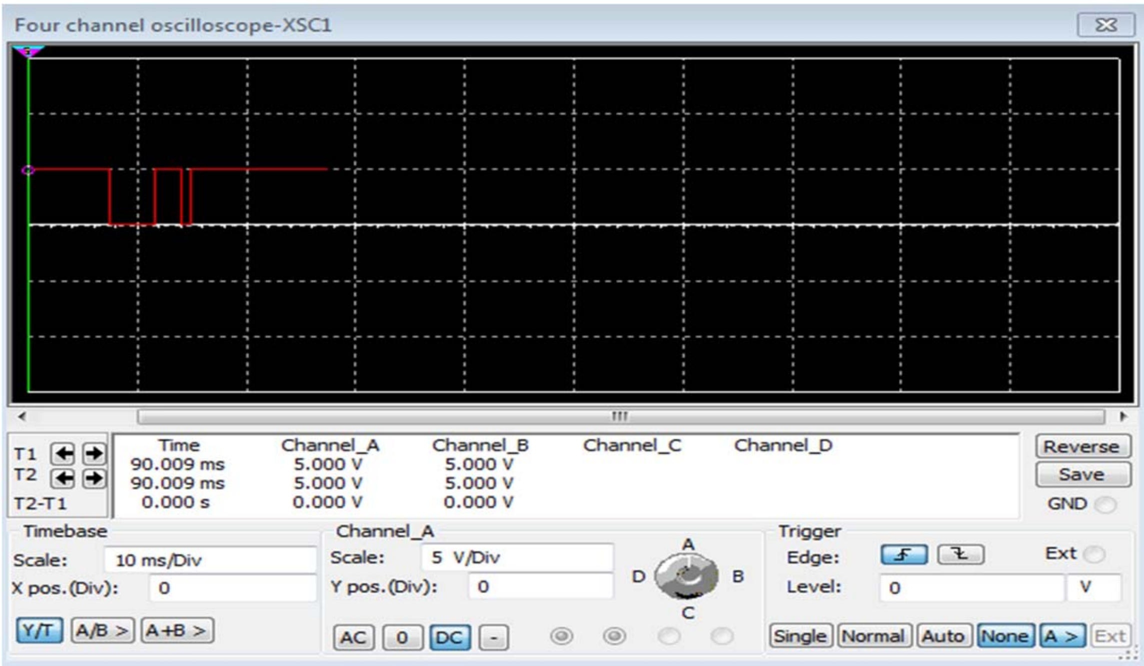

Fig. 5. Transmission of information to the Health Centre

IV. SIMULATION RESULTS

The prototype is simulated using the Multisim software, by rigging up the circuit. The sensors are interfaced to the micro controller 8052, to acquire the heart rate of the patient. Microcontroller is programmed to receive the obtained data. This data is transmitted to the nearest health centre using the GSM with proposed antenna. The doctor checks for the abnormalities in the patient, by observing the received parameters. The prescription is sent back to the patient for further treatment.

In order to avoid the problem of continuous power supply, we use piezoelectric beam, to drive the system. The simulation of the piezoelectric beam is done using MATLAB. Fig. 6 shows the designed two-layer, piezoelectric cantilever beam. When a voltage is applied across a piezoelectric beam, results in the bending of the beam. Similarly, if the beam is bent in the particular direction, voltage will be produced across the beam. The voltage produced is directly proportional to the amount of deflection along the coordinates. The proposed model for power source consists of a piezoelectric bimorph beam. The beam is called bimorph, since the both layer are made up of same materials.

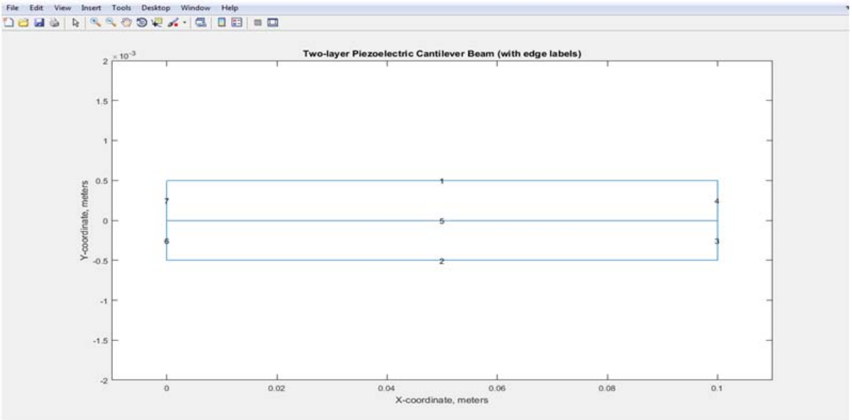

Fig. 6. Two layer Piezoelectric Cantilever Beam

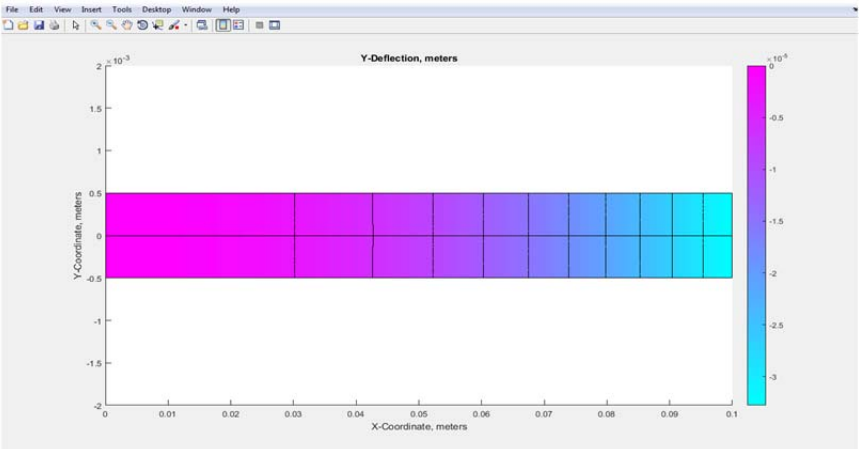

Fig. 7. Deflection in Y direction

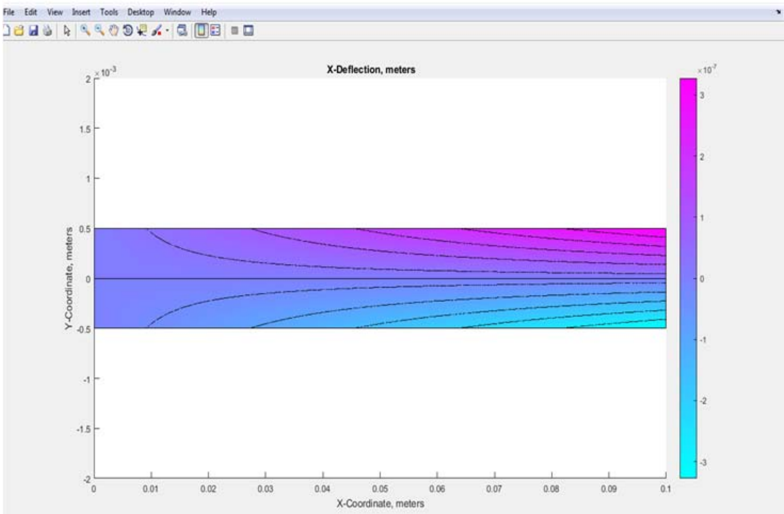

Fig. 8. Deflection in X direction

Fig. 7 and fig. 8 show the deflection in Y and X direction respectively. The voltage produced is directly proportional to the amount of deflection. The voltage produced is shown in the fig. 9.

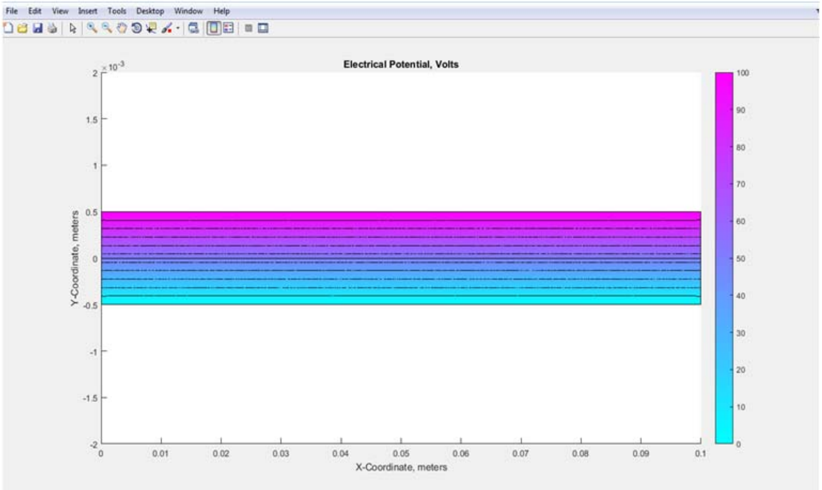

Fig. 9. Voltage Produced due to deflection

Polyvinylidene Fluoride (PVDF) is used as a material for the proposed bimorph beam. Polarization direction points downwards in the top layer and upwards in the bottom layer. The IEEE standard on piezoelectricity lists some of the standards for piezoelectric equation, which are given below by equation (1) and equation (2).

$$\varepsilon_1 = S_{11}\sigma_1 + d_{13}E_3 \text{ ---------- (1)}$$

$$D_3 = d_{31}\sigma_1 + e_{33}E_3 \text{ ---------- (2)}$$

Where,
ε = Mechanical Strain
σ = Mechanical Stress
E = Electrical Field
D = Electric Density
s = Elastic Compliance
d = Piezoelectric Strain Coefficient.
e = Electric Permittivity
Boundary conditions are denoted by super-scripts. The boundary conditions used are:
T = constant stress
S = constant strain
D = constant electrical displacement
E = constant field

MATLAB script is written for the configuration of the bimorph cantilever beam, and the material is configured for its properties and simulated. The configuration details used in MATLAB are as follows,

The bimorph material is Polyvinylidene Fluoride (PVDF)
Young's modulus (E1) = 2.0×10^9 N/m^2
Poisson's ratio (μ) = 0.29
Shear modulus (G12) = 0.775×10^9 N/m^2
Piezoelectric strain coefficients
(d_{31}) = 2.2×10^{-11} C/N
(d_{32}) = 0.3×10^{-11} C/N
(d_{33}) = - 3.0×10^{-11} C/N
Relative permittivity at constant stress = 1
The geometric properties are:
Beam length (L) = 100 mm
Layer thickness (H) = 0.5 mm

With the configuration details mentioned above, bimorph beam is simulated, and results are obtained. It is observed that, for the deflection of 33um, 100V of voltage is produced. Thus by employing the concept of piezoelectricity, the difficulty of charging and replacement of battery can be greatly reduced.

The microstrip antenna structure is simulated using MATLAB and HFSS for frequencies, 2.2 GHz, 2.5 GHz, and 2.4 GHz. The radiation pattern and antenna performance parameters are obtained for different frequencies. Table I shows the performance parameters of the antenna simulated at different frequency.

TABLE I
Microstrip Antenna Parameters

Frequency(GHz)	**Parameters**			
	Beam Width(degrees)	**Reflection Coefficient (dB)**	**VSWR (dB)**	**Return Loss(dB)**
2.2	72 (45, 117)	-0.977	20.82	0.9762
2.4	99 (27, 126)	-1.103	15.57	1.117
2.5	104 (22, 126)	-1.157	15.16	1.157

Fig. 10 shows the overview of the proposed microstrip antenna, which will be tested for different frequency range. Table I summarises the simulation Results obtained.

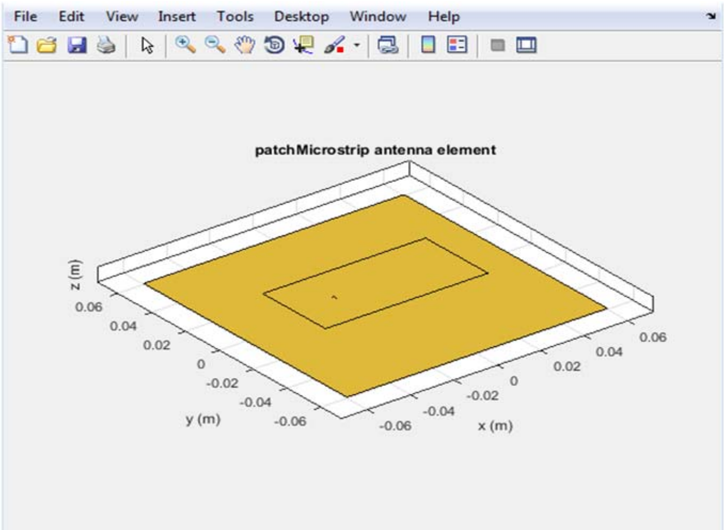

Fig. 10. Microstrip Antenna element

Fig.11, fig. 12, and fig. 13 show the radiation pattern for different frequency. For the frequency of 2.2GHz, the maximum value of directivity is found to be 5.96 dBi and 5.03dBi, 4.88 dBi, for 2.4GHz and 2.5GHz, respectively. It can be observed that the directivity in dBi, decreases with increase in frequency.

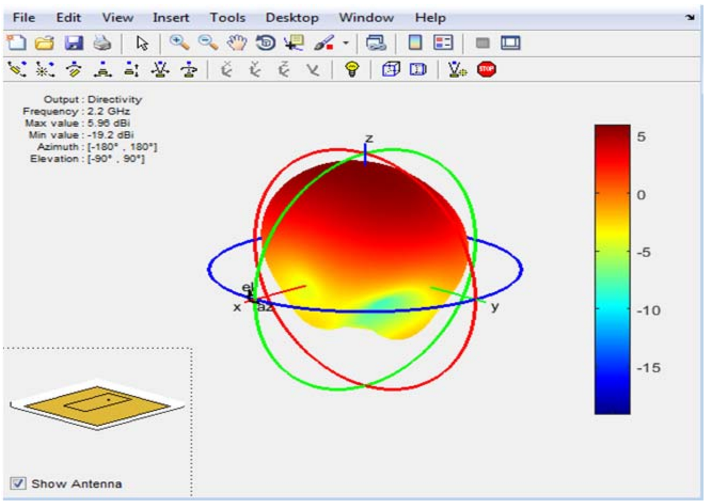

Fig. 11. Radiation Pattern for frequency 2.2 GHz

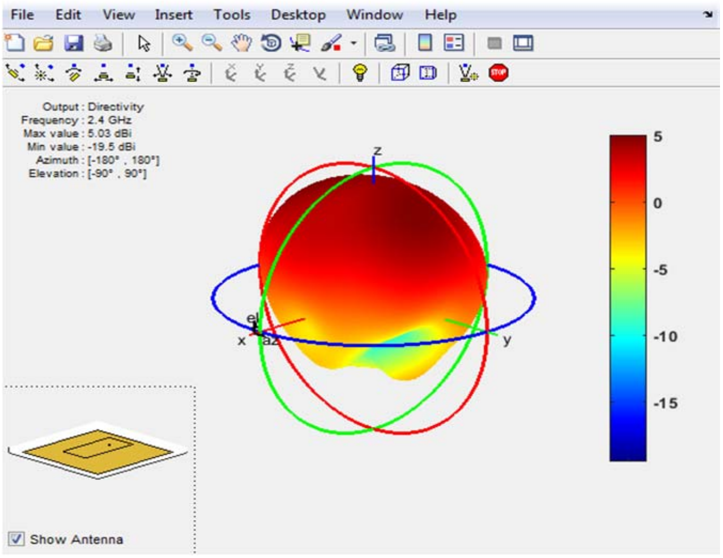

Fig. 12. Radiation Pattern for frequency 2.4 GHz

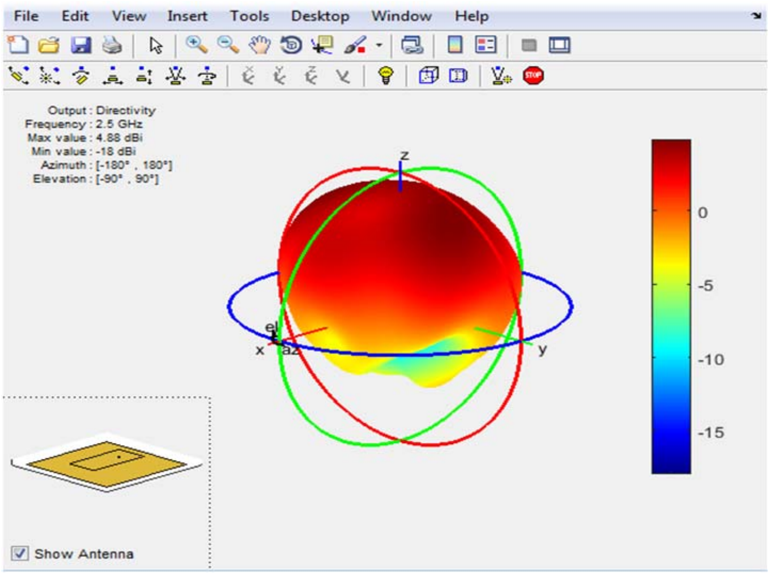

Fig. 13. Radiation Pattern for frequency 2.5 GHz

Directivity of an antenna is a measure of, how much does it concentrate its power in a given direction. It is always measured with respect to a standard antenna. Standard antnna is taken as an isotropic antenna. Mathematically directivity is given by equation (3).

$$D(\theta, \emptyset) = \frac{U_m}{U_\theta} \tag{3}$$

Where U_0 is the average radiation intensity produced by an isotropic antenna.

$$U_0 = \frac{W_{rad}}{4\pi} = \frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi} U(\theta, \emptyset)\, d\omega \tag{4}$$

Hence directivity of an isotropic antenna is 1, then directivity can also be given as mentioned in equation (5).

$$D(\theta, \emptyset) = \frac{U(\theta,\emptyset)}{U_{iso}} = \frac{P_r(\theta,\emptyset)}{P_{r,iso}} = \frac{P_r(\theta,\emptyset)}{\frac{W_{rad}}{4\pi r^2}} = \frac{4\pi U(\theta,\emptyset)}{W_{rad}} \tag{5}$$

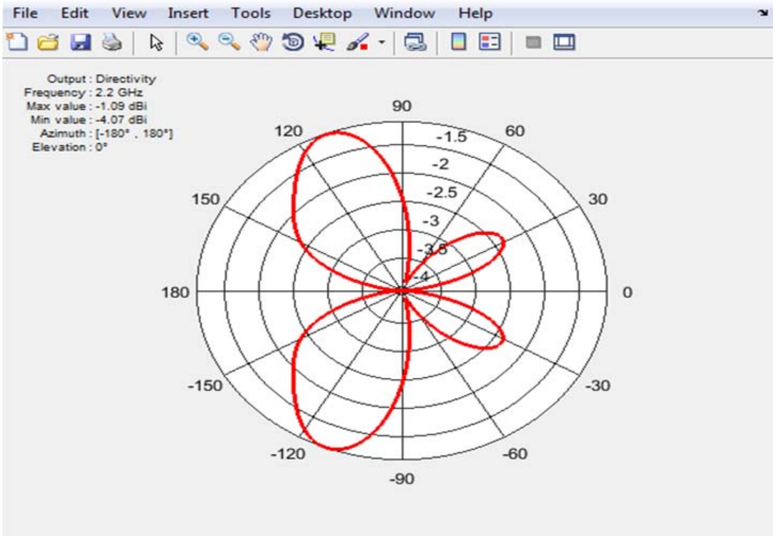

Fig. 14. Azimuthal Pattern for frequency 2.2 GHz

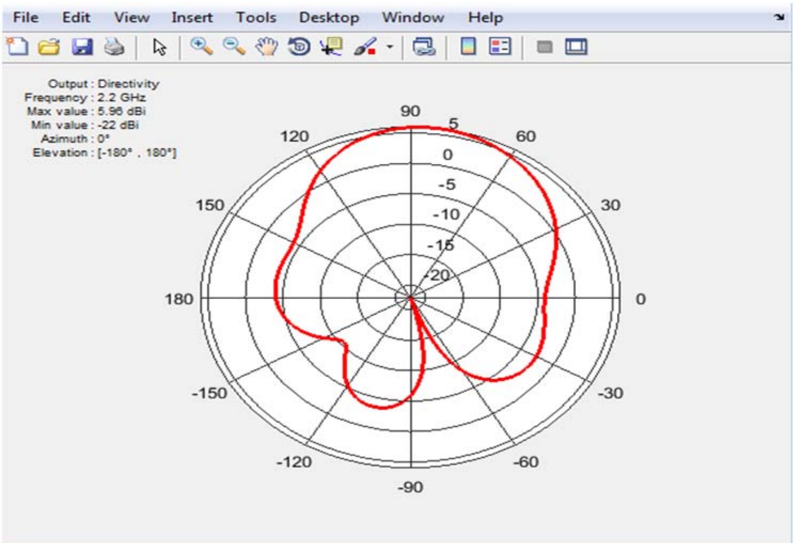

Fig. 15. Elevation Pattern for 2.2 GHz

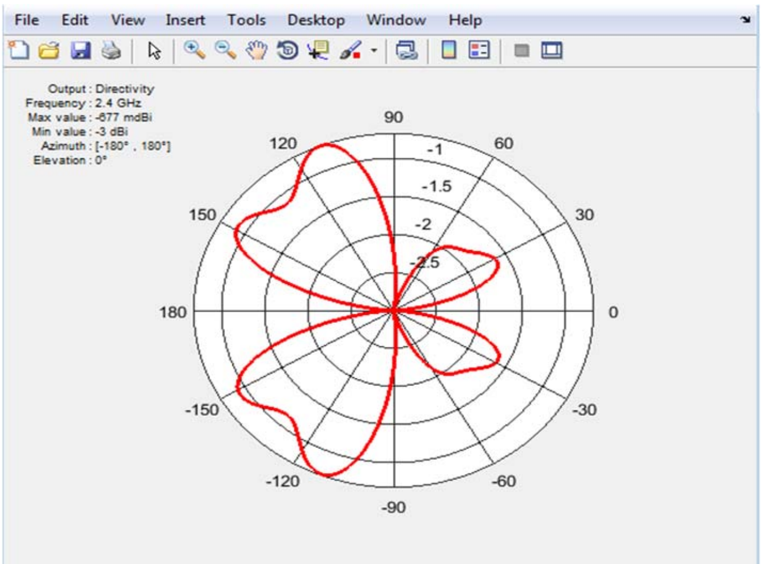

Fig. 16. Azimuthal Pattern for frequency 2.4 GHz

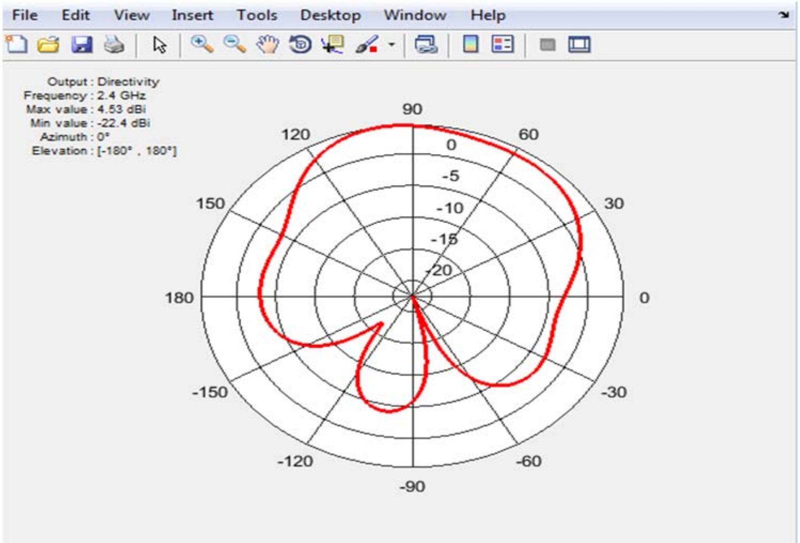

Fig. 17. Elevation Pattern for 2.4 GHz

Fig. 14 to fig. 19 shows the azimuthal and elevation pattern for the microstrip antenna at various operating frequencies. The proposed antenna is simulated for return loss, VSWR and also reflection coefficients.

Fig. 20, fig. 21 and fig. 22 shows the plot of return loss, reflection coefficient and Voltage Standing Wave Ratio, respectively.

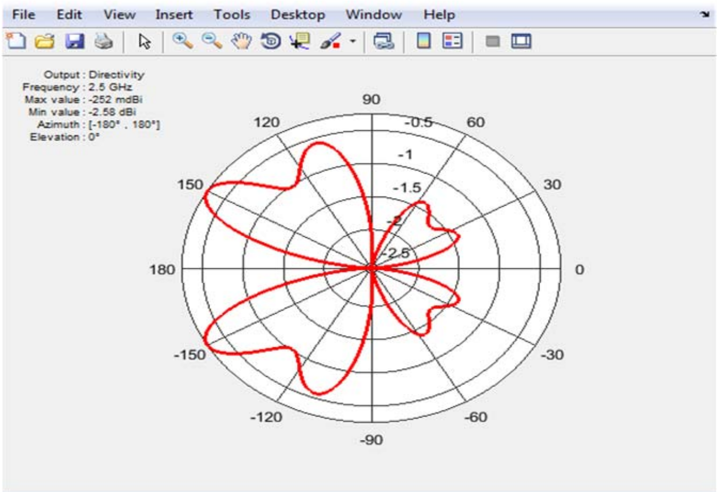

Fig. 18. Azimuthal Pattern for frequency 2.5 GHz

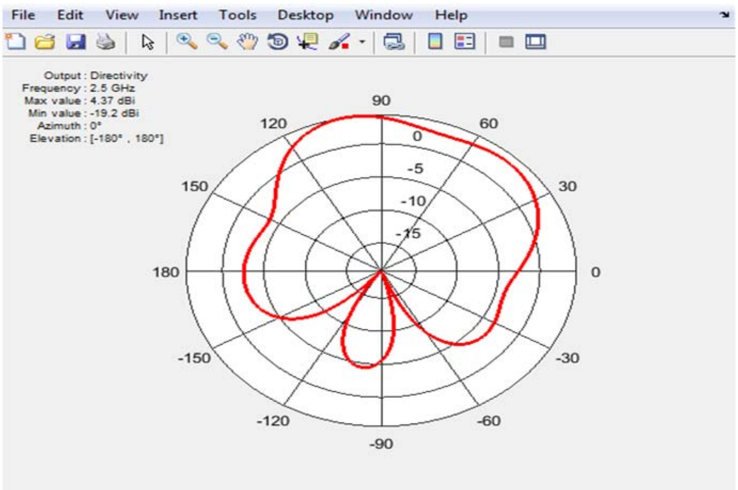

Fig. 19. Elevation Pattern for 2.5 GHz

Fig. 20. Plot of Return Loss

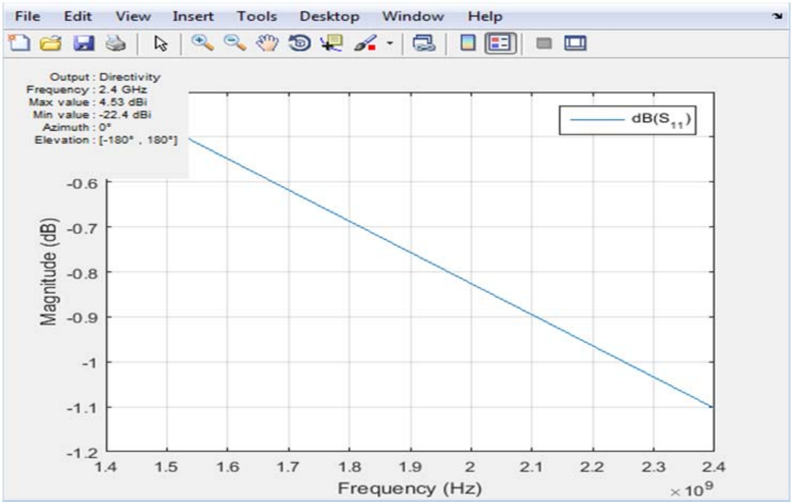

Fig. 21. Plot of Reflection Coefficient

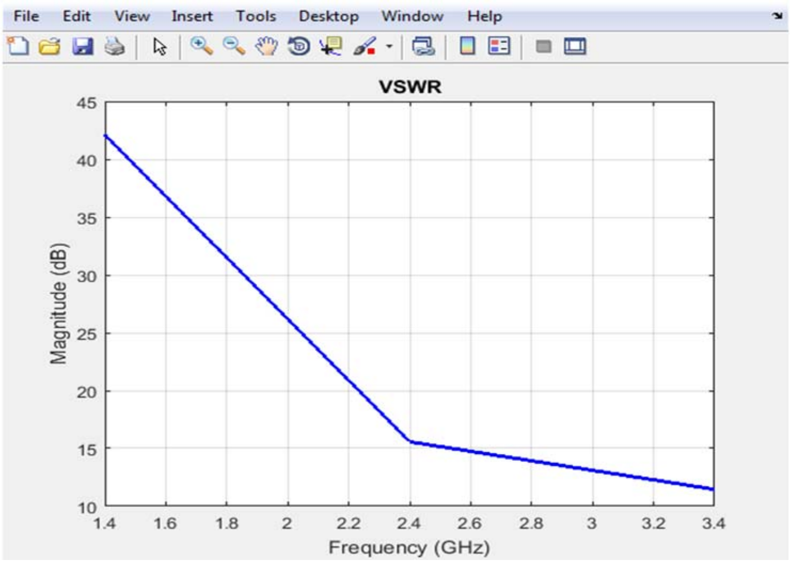

Fig. 22. Plot of Voltage Standing Wave Ration

The antenna is also simulated for its impedance characteristics and is presented in fig. 23.Impedance is one of the main properties of an antenna, which determines the transmission efficiency, of the system. Antenna should be properly matched, to reduce the reflection. Properly matched antenna could produce no reflection. The mathematical equation for impedance is given by equation (6).

$$Z_A = R_A + jX_A \tag{6}$$

Where, RA represents for real power to be dissipated by the antenna, either as ohmic loss or as radiation. Real power is dissipated in both cases. X_A allows power to be stored by the antenna, which we know happens from near field. Fig. 24 represents the simulation of microstrip using HFSS software. The radiation pattern and gain of the antenna is analysed and is presented in fig. 25 and fig. 26 respectively.

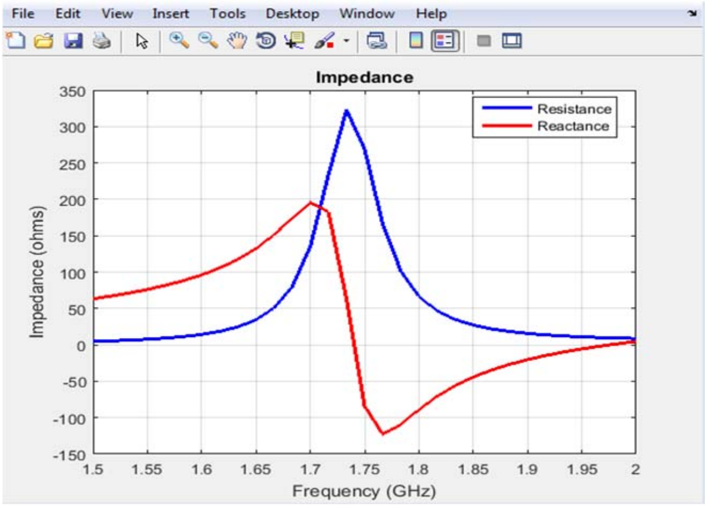

Fig. 23. Plot Showing the Resistance and Reactance

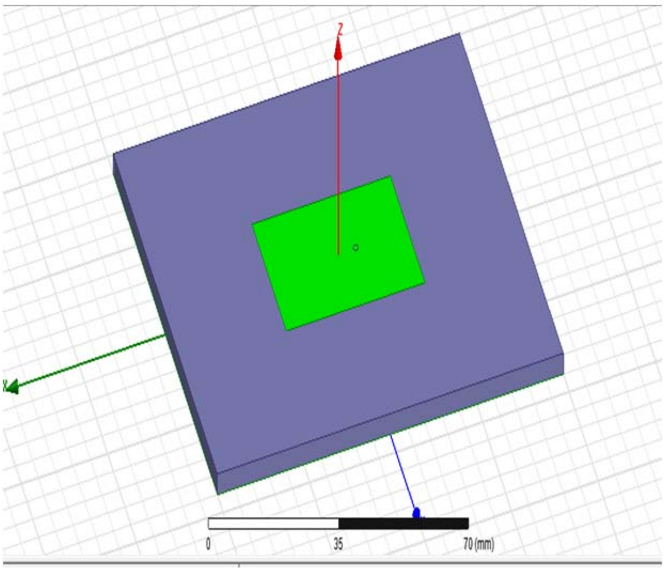

Fig. 24. Simulation using HFSS

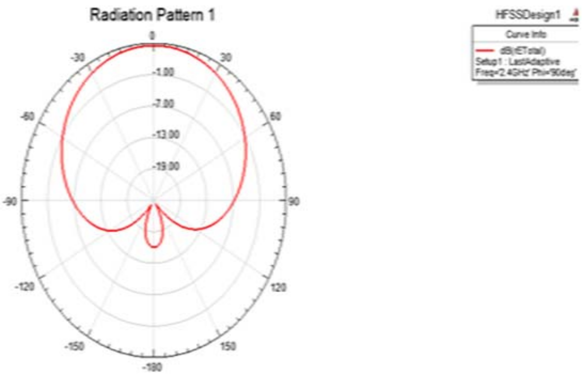

Fig. 25. Radiation patern as obtained by HFSS

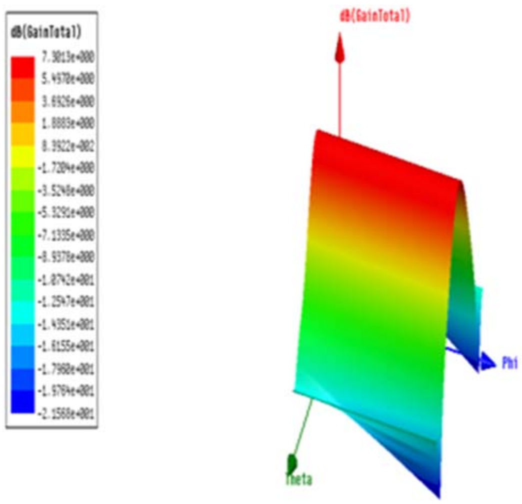

Fig. 26. Gain in dB

V. FUTURE SCOPE

The specific absorption rate of the proposed system will be analysed and the antenna will be customized according to the result .practical implementation and testing will be done in real time. The future scope also includes the design and implementation of the smart device for physically disabled.

VI. CONCLUSION

In this paper, we propose a new system to monitor the health condition of the individual, which is powered by the piezoelectric beam. Due to the problem of battery replacement and continuous charging of the gadget, it becomes very difficult to maintain the gadget. Thus we propose a new approach to eliminate this problem with the help of piezoelectric power driver. In order to increase the efficiency of transmission of the data, microstrip antenna is designed and simulated for different frequency range and the performance parameters are obtained and analyzed. The simulation of the piezoelectric beam is accomplished by MATLAB, which produced a voltage of 100V for 33um of deflection. Antenna simulation is done using HFSS and MATLAB and various performance parameters are obtained. The wearable device, which senses the heart rate of the individual, sends it to the nearest health centre, is accomplished by the 8052 microcontroller unit. The prototyping of the proposed system is done using Multisim, where the transmission and reception of data is analyzed. In the present busy life, it's very difficult to monitor the health condition of an individual. Thus the proposed system will greatly help in overcoming the problem of regular check up. The monitoring of the health can be done, without much difficulty and, the proposed system makes the life of an individual healthy.

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