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ANTENNA DESIGN FOR WEARABLE MEDICAL DEVICES USING MBAN BAND

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***Abstract*—With the number of wearable devices in Medical Body Area Network increasing day by day, it is also necessary for these devices to have a low profile, high gain and high directivity. We propose design for a High gain, microstrip line coupled low profile antenna with reflector using a FR4 material. Antenna array can be used for increasing the gain of antenna, but it makes antenna bulky. The use of a reflector strategically placed behind the main radiator increases the directivity and gain of antenna without using bulky array structure. The efficiency of antenna is very high which will ensure that maximum power will be radiated. The low profile of antenna makes it easy to be mounted onto a Wearable Devices in which size is the main concern. The antenna can be used for a variety of Wearable Devices working in MBAN i.e. IEEE 802.15.6.**

Keywords— ***Antenna design, Body Area Network, High gain, low profile, Microstrip Line, Wearable Devices***

I. INTRODUCTION

Body Area Network or Body Sensor Network (BSN) is a network of wearable devices used for medical applications. As shown in figure the body area network consists on one central Hub and number of Transmitters. The Hub is generally placed near the patient while nodes are the sensors which are mounted on the patient’s body to monitor its vitals. The Hub controls the communication between nodes. Hub and Nodes communicate with each other in 2.36GHz – 2.4GHz band.

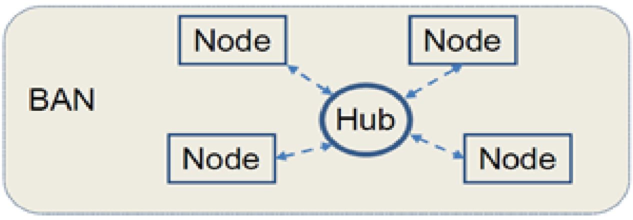

Fig.1. MBAN sensor network

The band of 2.36 GHz to 2.40 GHz is selected for the medical applications due to its clean spectrum and low interference sources. As the antennas are mounted on the body of the patient, it is necessary for the antenna to have a small footprint. The antenna should have a directive radiation pattern so the amount of radiation towards the skin tissues of the patient would be minimum. The size of antenna must be small so that it could be mounted easily on the body of the patient. High gain and High directivity are some added advantages. The problem of size can be solved by use of a microstrip antenna which has a very small size comparing to other antenna structures. The gain of antenna can be increased by using an Array of antennas. But use of array makes antenna very bulky. Microstrip antennas have an omnidirectional radiation pattern which is not desirable for wearable applications. Both of these problems are solved by using a reflector placed behind the main radiating patch. The reflector increases the gain of antenna as well as makes the radiation pattern of antenna directional. Microstrip antenna also has a facility of line feed which is not only simple, but also has small size than other feeding techniques. Thus a square shaped microstrip radiating patch structure with line feed is selected as the main radiator.

II. DESIGN OF MICROSTRIP PATCH

The center frequency of the MBAN band is 2.38 GHz. The antenna is designed such a way that it resonates at this center frequency. The main objective is to have a directional radiation pattern and High gain. The software used for simulation and design is HFSS (High Frequency Structural Simulator). The substrate material is FR4 material which has a dielectric constant of 4.4. The material is chosen because it is readily available. By performing all the calculations using 2.38 GHz as center frequency, the dimensions of the main radiating patch are 38.36 mm X 29.7 mm. The height of substrate is taken 1.6 mm. The width of the feed line is 3 mm which is used for impedance matching. To minimize impedance matching problem and improve gain of patch width of 1 mm slotted structure is introduced at feed line. The height of slot is varied until achieved desirable narrowband S11. So the slotted structure is 1 mm X 7 mm. Figure 2.1 shows the geometry of the microstrip patch.

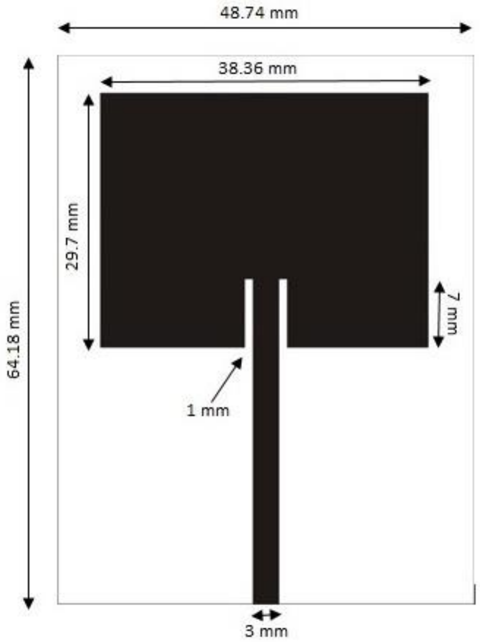

Fig. 2.1 Geometry of Microstrip Patch

The ground layer is designed using the optometric technique available in the HFSS software. The width and length of the ground surface is varied until maximum S11 value and maximum efficiency is obtained. This technique is called Defected Ground structure. The ground plane is intentionally modified to enhance the performance of the antenna. This improves the efficiency and directive properties of the antenna. Figure 2.2 shows the Defected ground structure used in the antenna design.

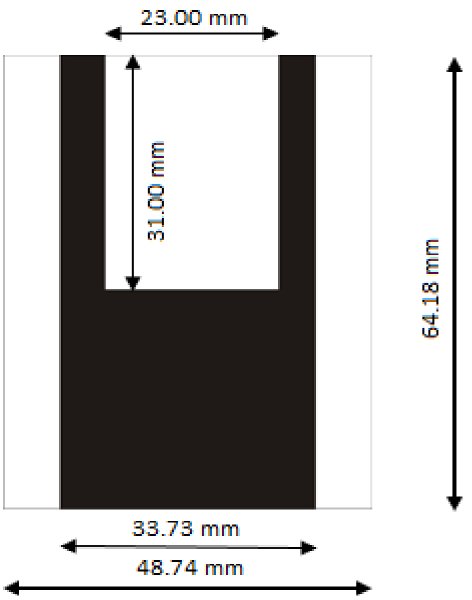

Fig. 2.2 Geometry of Defected Ground

To further increase the gain of antenna and to make the radiation pattern directional, a reflector is used. Figure 2.3 shows the reflector design. The reflector is placed behind the main patch. The reflector reflects the energy to the opposite direction of the antenna.

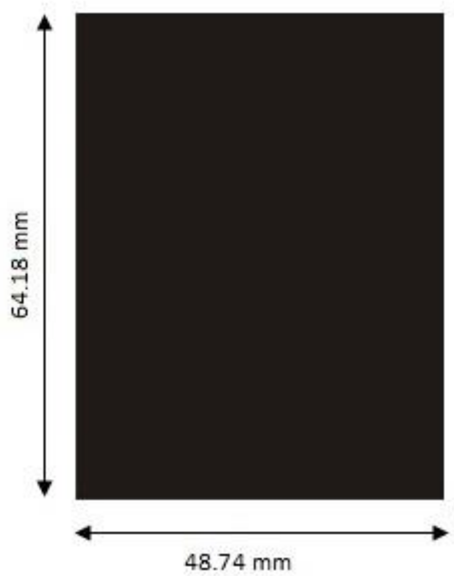

Fig. 2.3 Geometry of Reflector

This converts the omnidirectional pattern of the microstrip patch into a directional pattern having a small back lobe. The position of the reflector is determined using the same optometrics technique used for ground design. The optometrics technique is used to perform many iterations on the design. At 16 mm the S11 value is -19dB and efficiency is 72.10 %. Thus the air gap between patch and reflector is chosen at 16mm.

Table 2.1
Antenna Specifications

Sr. No.	Parameter	Value
1	**Centre Frequency (F_r)**	**2.38GHz**
2	**Dielectric Constant**	**4.4**
3	**Height of Substrate (h)**	**1.6mm**
4	**Width of Patch (W)**	**38.36mm**
5	**Length of Patch (L)**	**29.70mm**

Table 2.1 shows the specificatioins i.e resonace frequency ,height of substrate, height and width of patch element and dielectric constant.

III. EXPERIMENT AND RESULT

The microstrip patch and the reflector were fabricated using standard PCB board (FR4 material). An appropriate air gap was added in between patch and reflector. The vector network

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analyzer Rhodes- Schwartz Table top model was used to testing of microstrip patch antenna in free space. Figure 5 shows the setup of testing results of antenna using VNA. It has an operating range of 9 KHz to 15 GHz which is sufficient enough for testing the antenna. The measurements of Return loss (S11), Voltage Standing Wave Ratio (VSWR), Bandwidth and impedance were confirmed using vector network analyzer.

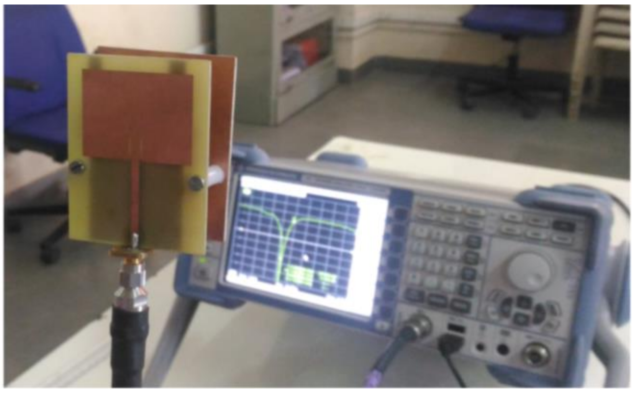

Fig. 3.1 Setup of Testing using VNA

Figure 3.2 shows the fabricated antenna return loss(S11), the return loss is amount of power loss in signal when reflected back from the antenna element. We have return loss of -22.80 dB and bandwidth ranging from 2.29 MHz to 2.42 MHz.The bandwidth is more broader due to ohmic loss i.e. soldering mismatch and fabricated material prototype.

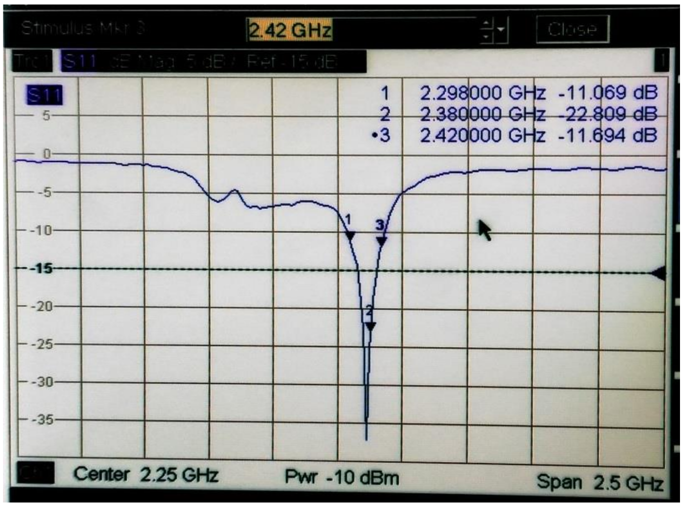

Fig. 3.2 Fabricated Antenna Return loss (S11)

We found small deviations in the fabricated and simulated reading of microstrip pathch. Figure 3.3 shows the Fabricated Antenna voltage standing wave ratio which is 1.1.Voltage Standing Wave Ratio is measure of matching between load impedance and source impedance.Figure 3.4 and 3.5 shows the simulated results of return loss and VSWR.

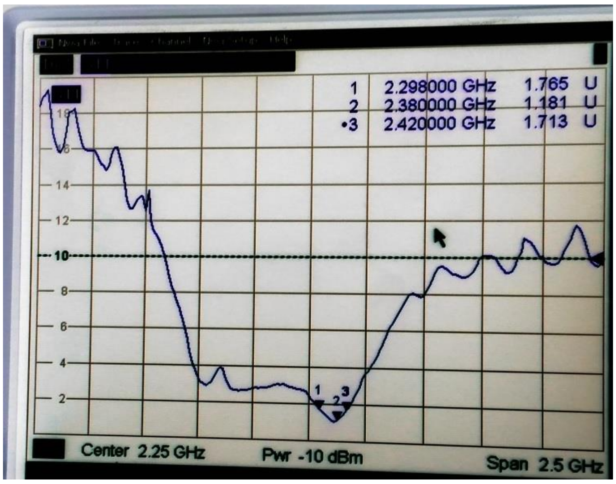

Fig. 3.3 Fabricated Antenna VSWR

For S11 = 0db, all the power is reflected back. Ideally the S11 value should be as high as possible. From simulations, the value of S11 is -19.56db.

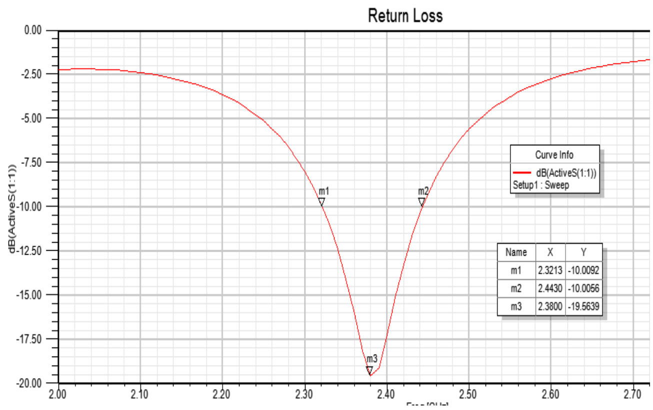

Fig. 3.4 Simulated Antenna Return loss (S11)

The ideal value for VSWR is 1. The smaller the VSWR value, better the antenna is matched with transmission line. From simulations, the VSWR value for dipole is 1.23.

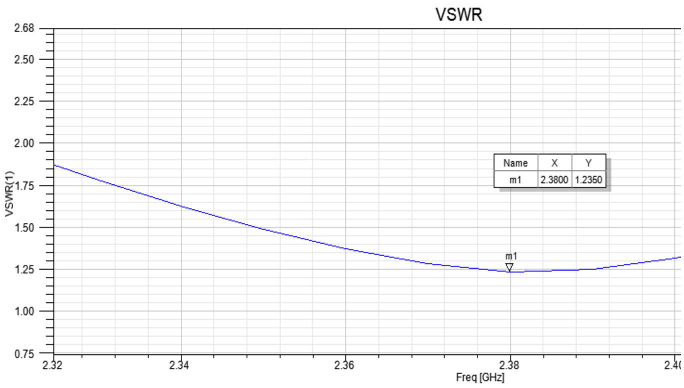

Fig. 3.5 Simulated Antenna VSWR

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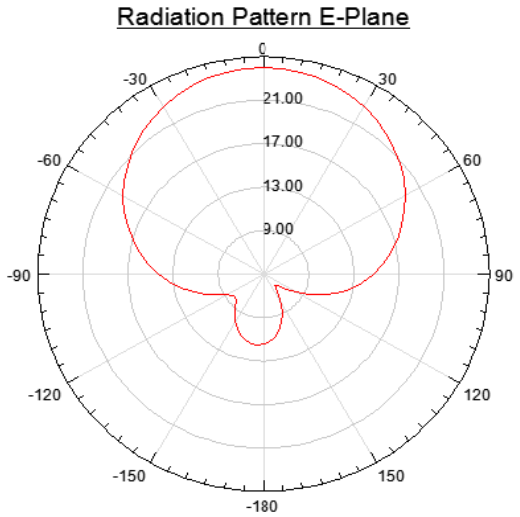

Fig. 3.6 Radiation Pattern

An antenna radiation pattern or antenna pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. The E-plane is defined as "the plane containing the electric field vector and the direction of maximum radiation". By placing reflector along with patch element the omnidirectional radiation pattern of antenna become more directional.

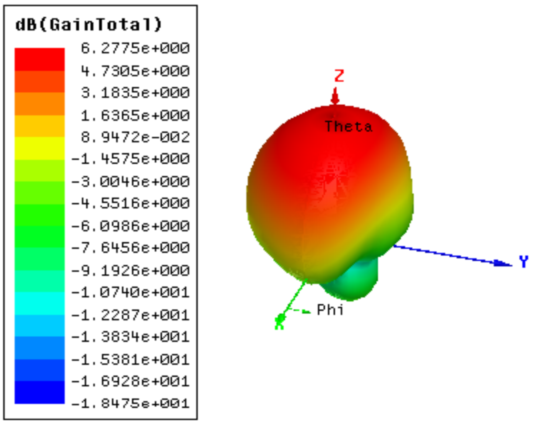

Fig. 3.7 Gain in 3D

Gain is the ratio of maximum radiation intensity from test antenna in a given direction to the maximum radiation intensity from reference antenna when same amount of power is applied to both transmitting and receiving antenna. Ideally the value of gain should be greater than one. The simulated results show that the gain of antenna is 6.23 dB.

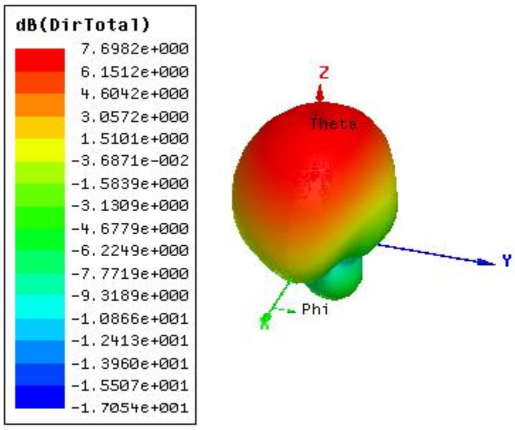

Fig. 3.8 Directivity in 3D

Directivity of an antenna defined as "the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. Our antenna has directivity of 7.69 dB.

Table 3.1
Experiment Result

Parameter	Simulated Result	Fabricated Result
Return loss	**-19.56 dB**	**-22.80 dB**
VSWR	**1.23**	**1.1**
Gain	**6.27 dB**	**6.2 dB**
Directivity	**7.69 dB**	**7.65 dB**
Input Impedance	**50 Ω**	**45.8Ω**
Efficiency	**72.10 %**	**72.4%**

Table 3.1 show the similarities in simulated result using and fabricated result of antenna.

IV. CONCLUSION

Based on the results of simulations and fabricated antenna we can say that the antenna resonates perfectly at the Centre frequency 2.38GHz. The antenna has S11 value of - 22.80dB at the given frequency. Such a low value of S11 ensures that very little power is reflected back to antenna. Our second objective was to make the antenna pattern directional which is also achieved by designing a reflector and placing it below the antenna. The use of reflector has given the directivity of 7.69dB in simulations. The gain of antenna is also high considering the limitations of the microstrip antenna. By using optimetric technic, we achieved gain of 6.27dB on FR4 material. The efficiency of antenna is 72.10 %. The fabricated antenna also has desired bandwidth which covers the MBAN band of 2.36 GHz to 2.40GHz.The size of antenna is small enough to be used for wearable applications. Due to all these characteristics of antenna it can be easily used for the wearable devices working in MBAN band.

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