Design of a Compact Microstrip Antenna for Medical Application at 2.38 GHz

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ABSTRACT
This paper presents the design of a compact microstrip patch antenna, the compactness is achieved by making two slots in the patch and shorting the patch along its width with the ground plane. The compact antenna has good performance in terms of VSWR, return loss, etc. as compared to calculated antenna. The compact antenna is operating at 2.38 GHz in Medical Body Area Network band (2.36-2.39 GHz), the antenna is fabricated on a FR-4 substrate. The co-axial feeding technique is used to match the input impedance since co-axial feeding is easy to adjust and can be given at any location to obtain good return loss.

General Terms
Medical Body Area Network

Keywords
MBAN; Compact Microstrip Antenna; co-axial feeding; FR-4 substrate; HFSS;

1. INTRODUCTION
Medical Body Area Network (MBAN) is a new band (2.36-2.39 GHz) for medical application specified by the FCC based on the proposal given by Philip Healthcare, GE Healthcare and the Aerospace and Flight Test Radio Coordinating Council (AFTRCC). In this approach, there are large numbers of sensor which are placed on or around a person's body which senses the various physiological parameters like body temperature, blood glucose level, ECG etc. and transmit the data wirelessly to the hub device where data processing is done to start a treatment procedure of the patient [1]. WBANs has attracted many researchers because of its various benefits such as it will increase the patient mobility and comfort, it can provide better infection control since it is non-invasive. There are also some other frequency bands assigned to the medical application such as Medical Implant Communication system (MICS), Medical Device Radio communication Service (MED Radio), 2.4 GHz ISM (Industrial, Scientific and Medical) band, the Wireless Medical Telemetry Service (WMTS) band and Ultra Wideband (UWB 3.1-10.6 GHz)[1] [2]

For placement of antenna near the body the polarization of antenna is required in the normal direction to the body surface which reduces the effect of electromagnetic wave on the human body, it should radiate away from body i.e unidirectional [3] [4]. Patch antenna is the best candidate for MBAN application since it has a omnidirectional radiation pattern which minimize the effect of the human body as well as reduce the body exposure to electromagnetic (EM) field [3] [4]. Since the MBANs devices are very close to human body it should have small size and also the radiated power should be at a safer level, patch antenna can satisfy the requirement for MBANs application. So in this paper the objective was to design a patch antenna which will operate in MBAN band (2.36-2.39GHz). The FR-4 substrate is used for the designing of patch antenna. Concept of antenna design and calculation of various parameters is introduced in section II, section III describes the result of simulation in HFSS, section IV provides Conclusion and section V gives information about future work..

2. ANTENNA DESIGN APPROACH
The design of rectangular micro strip patch antenna has been done by applying following steps:

Step I:

To calculate the resonance frequency f_0:

$$\boldsymbol{f_0} = \frac{f_U + f_L}{2} \qquad \textbf{(1)}$$

Since $f_U = 2.39$ GHz and $f_L = 2.36$ GHz therefore we get resonance frequency $f_0 = 2.375$GHz.

Step II:

To calculate patch width W [5]:

$$W = \frac{c}{2f_0\sqrt{\frac{\epsilon_r+1}{2}}} \qquad (2)$$

Where c=3x10^8 m/s, which is the velocity of light in free space, f_0Is the resonant frequency, here we are using a FR-4 epoxy substrate which have ϵ_r=4.4, by putting all the value in above formula we get the width of patch W=3.84cm.

Step III:

To calculate effective dielectric constant ϵ_e [6]:

$$\epsilon_e = \frac{(\epsilon_r+1)}{2} + \frac{(\epsilon_r-1)}{2}\left[1 + \frac{12h}{W}\right]^{-0.5} \qquad (3)$$

For h=0.16cm the effective dielectric constant is found as 4.088.

Step IV:

To calculate length extension ΔL[5]:

$$\Delta L = 0.412h\frac{(\epsilon_e+0.3)(\frac{W}{h}+0.264)}{(\epsilon_e-0.258)(\frac{W}{h}+0.8)} \qquad (4)$$

By putting the value of W, h and ϵ_e , ΔL is obtained as 0.07376cm.

Step V:

To calculate effective length L_e[5] [6]:

$$L_e=\frac{c}{2f_{0}\sqrt{\epsilon_e}} \qquad (5)$$

=3.12cm

Step VI:

To calculate length of the patch, L [5]:

$$L=L_e-2\Delta L \qquad (6)$$

Now the length of patch L=2. 974cm.

Using above calculated value a rectangular micro strip patch antenna is designed in HFSS (High Frequency Structural Simulator) software.

3. SIMULATION RESULTS

3.1 Initial patch antenna

First a Microstrip patch antenna is designed based on the previously calculated parameter operating at 2.31 GHz. Then to reduce the size of the patch ground plane is shorted with the width of the patch which will reduce the size of the patch to half of the previous one [6]. Further size reduction is done by making two slots in the patch[9]. The resonance frequency is adjusted by varying slot width and the width of the sorting plate. The shorting plate has a width of 0.28mm and a length of 1.4cm. The two slots on the patch have a width of 0.3mm and length of 11mm. The reduced antenna has more return loss and VSWR as compared to previous one. The calculated value of antenna at 2.375 GHz is summarized in table 1

Table 1 Dimension of initial antenna

S. NO.	Parameters	Value
1.	Patch length	2.974cm
2.	Patch width	3.84cm
3.	Resonance frequency	2.375GHz
4.	Substrate dielectric constant	4.4
5.	Dielectric loss tangent	0.02
6.	Substrate and ground plane size	6cm x 6cm
7.	Coaxial feed position	(0,0.7cm)

3.1.1 Return loss

Return loss represents how much power is reflected from the antenna. For most of the practical application return loss of -10 dB is sufficient. Return loss is calculated in HFSS by taking the frequency sweep from 2-3 GHz with solution frequency of 2.38 GHz. The return loss is found to be -13.9536 dB at 2.31 GHz. Return loss of antenna should be as low as possible. Ideally, it should be -∞ [7].

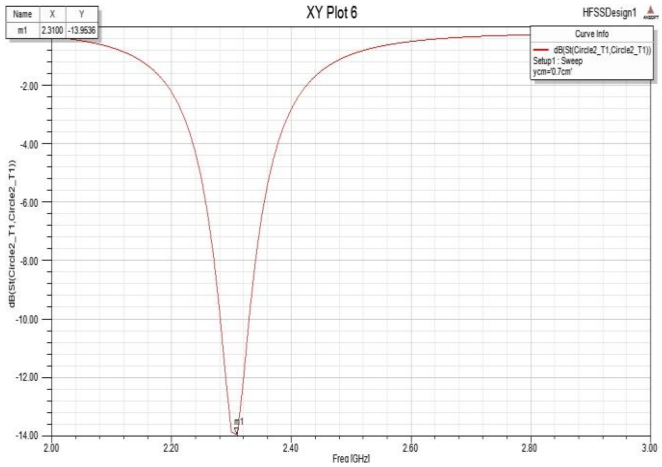


Fig 1: Return loss of initial patch antenna

3.1.2 VSWR

VSWR is a measure that describes how good the antenna is matched to the radio or transmission line. It should be as low as possible. The VSWR vs frequency plot is obtained in HFSS by taking the frequency sweep from 2-3 GHz and solution frequency of 2.38 GHz. The VSWR at frequency 2.31 GHz is found to be 1.5067. For antenna the ideal value of VSWR should be equal to 1[8]. In practical application it should be less than 2.

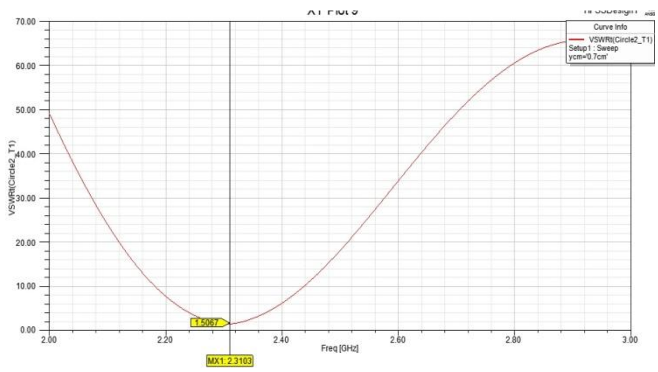


Fig 2: VSWR of initial patch antenna

3.1.3 Radiation pattern

The radiation pattern is a graphical representation of radiation properties of the antenna. The E-plane and H-plane plot of radiation pattern is obtained in HFSS by inserting a far-field sphere. The radiation pattern for $\emptyset = 0°$ and $\emptyset = 90°$ is shown below:

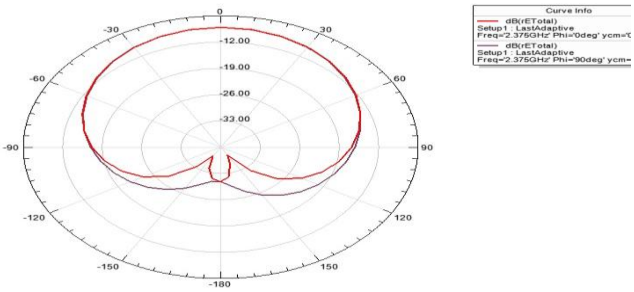


Fig 3: Radiation pattern of initial patch antenna

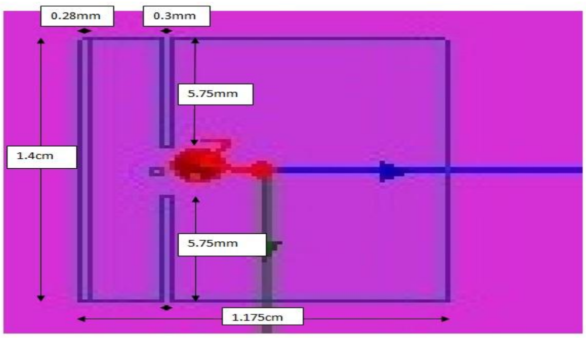
3.2 Compact sized patch antenna

The dimension of compact patch is given below in Table 2

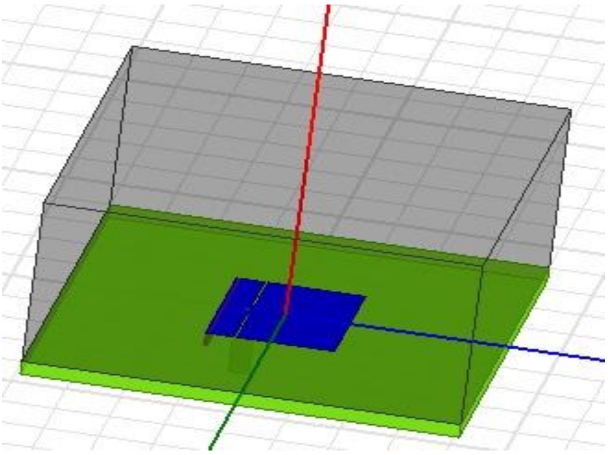
Table 2 Dimension of compact antenna

S. NO.	Parameter	Value
1.	Patch length	1.175cm
2.	Patch width	1.4cm
3.	Dielectric constant	4.4
4.	Loss tangent	0.02
5	Substrate and ground size	4cm x 4cm
6.	Resonance frequency	2.38 GHz
7	Feed position	(0cm,-0.35cm)
8	Slot dimension	5.75mm x 0.3mm
9	Shorted plate dimension	1.4cm x 0.28mm

The geometry of the antenna in HFSS is shown below:



(a)



(b)

Fig 4: Antenna in HFSS (a) With Patch dimension and (b) patch with substrate in airbox

3.2.1 Return loss

Return loss represents how much power is reflected from the antenna. For most of the practical application return loss of -10 dB is sufficient. Return loss is calculated in HFSS by taking the frequency sweep from 2-3 GHz with solution frequency of 2.38 GHz.Return loss of compact made patch antenna is found to be -26.3894 dB at resonance frequency of 2.38 GHz.

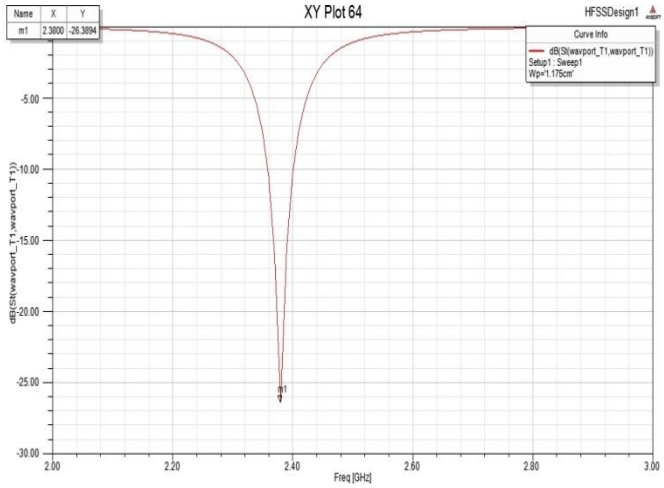


Fig 5: Return loss of compact antenna

3.2.2 VSWR

VSWR is a measure that describes how good the antenna is matched to the radio or transmission line. It should be as low as possible.The VSWR vs frequency plot is obtained in HFSS by taking the frequency sweep from 2-3 GHz and solution frequency of 2.38 GHz.The VSWR of compact antenna is 1.114 at resonance frequency of 2.38 GHz. The VSWR is improved as compared to the initially designed antenna which have VSWR of 1.5067 at resonance frequency.

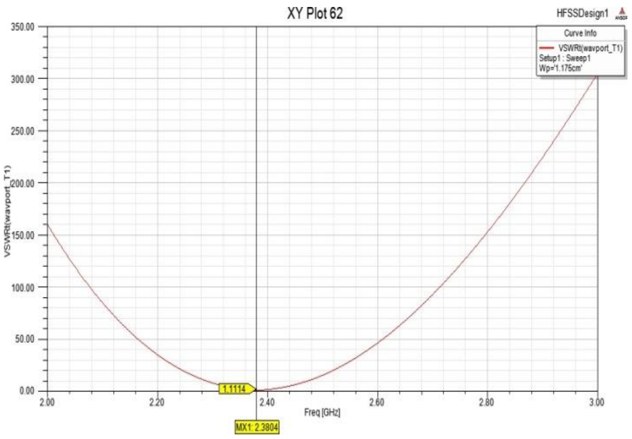


Fig 6: VSWR of compact antenna

3.2.3 Radiation pattern

The radiation pattern is a graphical representation of radiation properties of the antenna. The E-plane and H-plane plot of radiation pattern is obtained in HFSS by inserting a far-field sphere.The radiation pattern of a compact patch antenna for $\emptyset = 0°$ and $\emptyset = 90°$ is shown below:

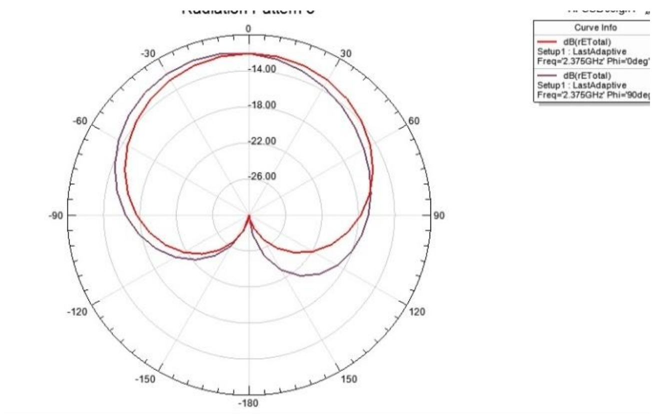


Fig. 7 Radiation pattern of compact patch

The Table 3 below shows the comparison between the two antennas:

Table 3 Comparison between two antennas

S.NO.	Parameter	Initial patch antenna	Compact patch antenna
1.	Return loss	-13.95 dB	-26.38 dB
2.	VSWR	1.5067	1.114
3.	Operating frequency	2.31 GHz	2.38 GHz

4. CONCLUSION

This paper mainly focuses on the miniaturization of patch antenna and its effect on the antenna parameter. First the calculated value is simulated which give return loss of -13.95 dB at 2.31 GHz and VSWR of 1.5067. And then in the second case a compact antenna is designed, which operate in MBAN band at 2.38 GHz with a return loss of -26.38 dB and VSWR of 1.114. There is significant improvement in return loss and VSWR as compared to initial design and also the compact antenna operates at 2.38 GHz MBAN band and thus can be used for MBAN application.

5. FUTURE WORK

In the future different substrate material will be used to improve the performance and also the effect of human body on antenna performance will be investigated. Fabrication and testing of antenna will be done.

6. ACKNOWLEDGMENTS

I would like to thank my Guide Sadhana pai and Co guide Nishan patnaik for their valuable support, guidance and encouragement.

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