
Examining the Effect of Human Body to the Performance of Antenna in Wireless Body Area Network

By

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ABSTRACT

Wireless body area network (WBAN) is fast becoming the future of wireless communication. However, one of the major challenge is for WBAN gadgets to operate in the vicinity of human body. The effects of human body to the performance of antenna is examined in this research, and it was discovered to have effects on the resonant frequency, radiation pattern and the overall efficiency of the antenna. The effect is studied using human body model in CST microwave studio using antenna, designed for 5GHz ISM bandwidth. It was discovered that, human body has less effect on the resonant frequency but more effects on the radiation pattern.

Keywords: Dielectric permittivity, specific absorption rate, radiation efficiency.

INTRODUCTION

The major constraints impose by human body to the performance of wearable antennas includes but not limited to the frequency detuning, radiation pattern deformation and impedance variation in the feeding point [1]-[2], all these can be attributable to electromagnetic absorption by the surrounding tissues. In wearable antenna design, these constraints cannot be neglected, it must be taken into consideration in the design process. However, two main factors determine the gravity of the impact on the performance of the antenna.

Position of the antenna on human body

Generally speaking, this kind of antennas are designed for on, off, or in body communications. For in-body communications, the antennas are generally designed to be implanted within the body mass and are mainly used for medical applications. For off-body communications, antennas are place in the body to communicate with mainly base stations or broadcast stations. And for the on-body communications, the main propagation channel is the human body surface.

The surrounding tissues

Human body is a complex, inhomogeneous, irregular, and a stratified dielectric medium. Anatomically speaking, human body consists of skin, fat, muscles and bones that sheltered some sensitive and delicate organs, such as heart, lungs in the abdomen, and brain in the head region

and so on. Each of those entities that make up the body have some distinct dielectric properties with unique effect on the performance of the antenna. The summation of these individual effects entirely alter the performance of the antenna. Another factor that also plays a critical impact on the performance of the wearable antennas is the mass density of a particular tissue in a particular area. All these are required to be taken into consideration in the design process. In order to predict the effects of human body on antenna with high degree of accuracy, a phantom data in [3] is adopted. It was obtained from computed tomography scan and magnetic resonance imaging data of two men. The permittivity and conductivity [3]-[5] of some human tissues at 1GHz are presented in table 1.

EFFECTS OF RADIATION TO HUMAN BODY

Another critical consideration in the design of wearable antenna is the effect of E.M radiation to the human body. Federal Communication Commission (FCC) [6]-[7] and some other organisations has set a threshold to limit the exposure of human body to electromagnetic radiation. The quantity of E.M radiation absorbed by human body is termed as specific absorption rate (SAR) and is measured in watts per kilograms (w/kg). Fig.1 presented a simulated result of exposing human ear region to electromagnetic radiation from the mobile phones.

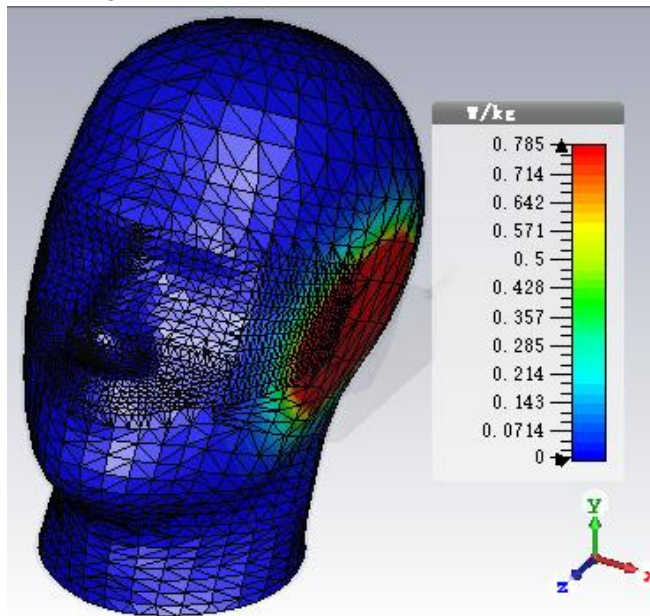


Figure 1: Effect of E.M radiation to human body, simulated in CST microwave studio.

ANTENNA PROXIMITY TO HUMAN BODY

Human body basically degrades the performance of wearable antennas, the effects can be seen directly on the resonant frequency, efficiency, and radiation pattern. In this section, we studied the effects of the proximity to human body using a human body model that consists of skin, fat and muscle. A simple rectangular patch antenna is designed to study this effect, the antenna is fed using microstrip feedline and the patch has a dimension of 20mm×25mm, it’s designed on 40mm×40mm×1.4mm Fr-4 substrate. The antenna is excited for single band with central frequency at 5GHz in free space that is when no human body is attached to it as shown in fig.2. The return

loss and the radiation pattern shown in fig.3a and fig.3b respectively are used as a benchmark to determine how the performance can be affected by the human body proximity.

Table 1: present dielectric properties of human tissues at 1GHz

S/N	Tissue	Permittivity (ϵ_r)	Conductivity [S/m]
1	Dry Skin	40.936	0.900
2	Fat	5.447	0.056
3	Bone Cancellous	20.584	0.364
4	Muscles	54.811	0.978

Human tissues are basically classified into two i.e. tissues with low water content and tissues with high water content, to see the effect of each we studied the effect of some individual tissues like skin, fat and muscle in the performance of the antenna.

The antenna dimensions can be determined using equations 1 to 5 [8]-[9].

$$W = \frac{c}{2f_r} \sqrt{\frac{2}{(\epsilon_r + 1)}}, \tag{1}$$

Where c is the speed of light in free space and f_r is the resonant frequency. The microstrip patch lies between air and dielectric material, Hence the electromagnetic waves see an effective permittivity ϵ_{eff} given by equation 2.

$$\epsilon_{eff} = \left[\frac{\epsilon_r + 1}{2} \right] + \left[\frac{\epsilon_r - 1}{2} \right] \left[1 + \frac{12h}{W} \right]^{-\frac{1}{2}}, \tag{2}$$

The patch length (L) determines the resonant frequency and is given by equation 3

$$L = \left[\frac{c}{2f_r \sqrt{\epsilon_{eff}}} \right] - 2\Delta L, \tag{3}$$

Where ΔL the increase in length of the patch due to infringing is field along the length of the patch and is given by equation 4.

$$\frac{\Delta L}{h} = 0.412 \left[\frac{\epsilon_{eff} + 0.3}{\epsilon_{eff} - 0.258} \right] \left[\frac{\frac{W}{h} + 0.264}{\frac{W}{h} + 0.8} \right], \tag{4}$$

The effective length L_e is given by 4.20

$$L_e = L + \Delta L. \tag{5}$$

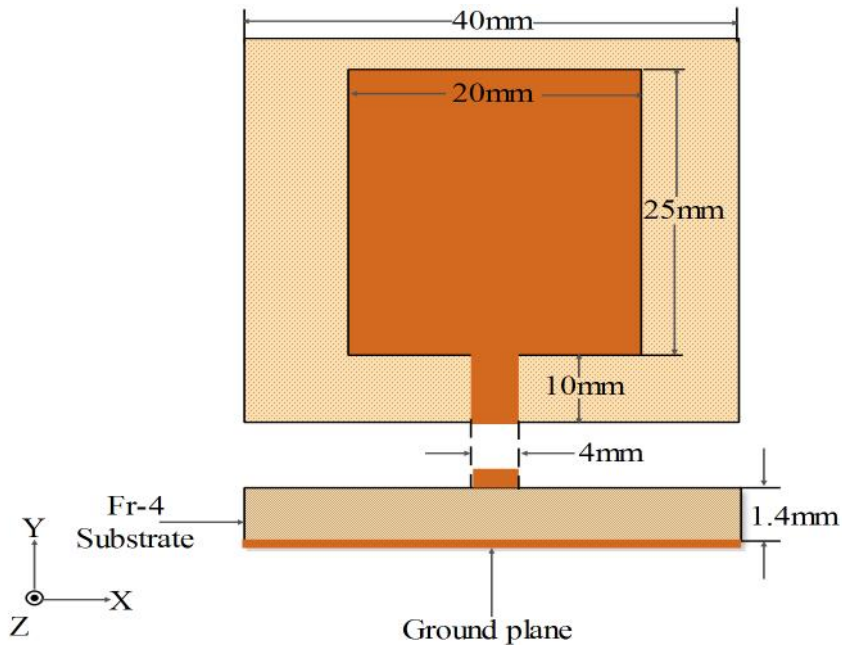


Figure 2: Antenna design architecture.

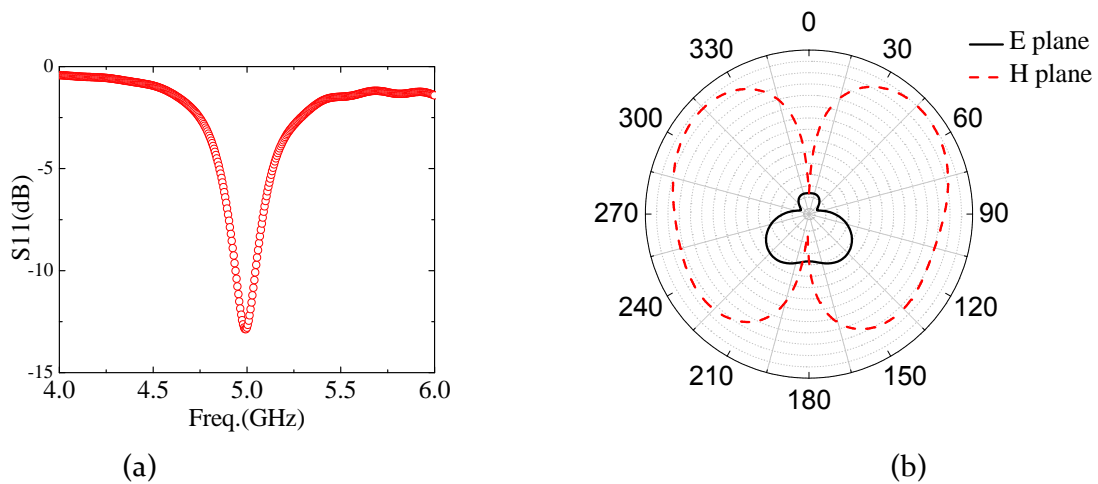


Figure 3: (a) Simulated return loss (b) Simulated radiation pattern.

EFFECT OF HUMAN SKIN

Skin is the outer most layer of human body that is considered to be in the class of high water content tissues in human body. Human skin in a dried condition have dielectric constant of 40.936 and conductivity of 0.9000S/m. The analysis is carried out in CST microwave studio with human skin having permeability of 1 and density of 1100kgm⁻³. To study the effect of human skin, the antenna shown in figure 2 has been used directly on human skin with thickness of 1mm, 2mm, 5mm and 10mm, it can be seen from figure 4 that the skin has little effect on the frequency bandwidths, furthermore, the return loss of the antenna is not highly affected by the thickness of the skin. The radiation pattern is highly affected by and even worst as the thickness of the skin increases. Figure 5 shows that at a thickness of 1mm to 2mm the radiation pattern is not much affected but as the

thickness increase to 5mm the radiation pattern became more affected, when the thickness increases to 10mm more side lobes emerged behind the main lobe, this shows that the higher the thickness of the skin the more the side lobes.

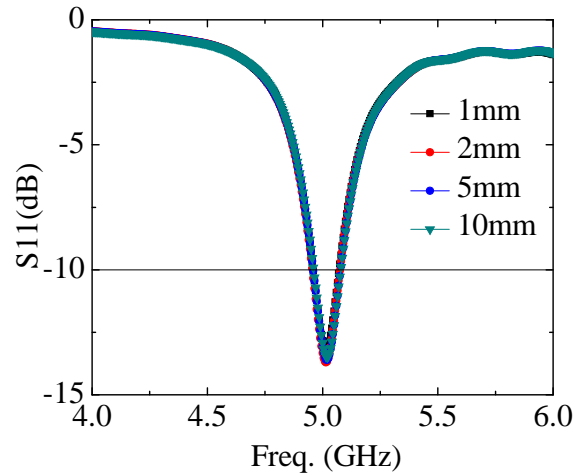


Figure 4, Simulated antenna on human skin with different thickness.

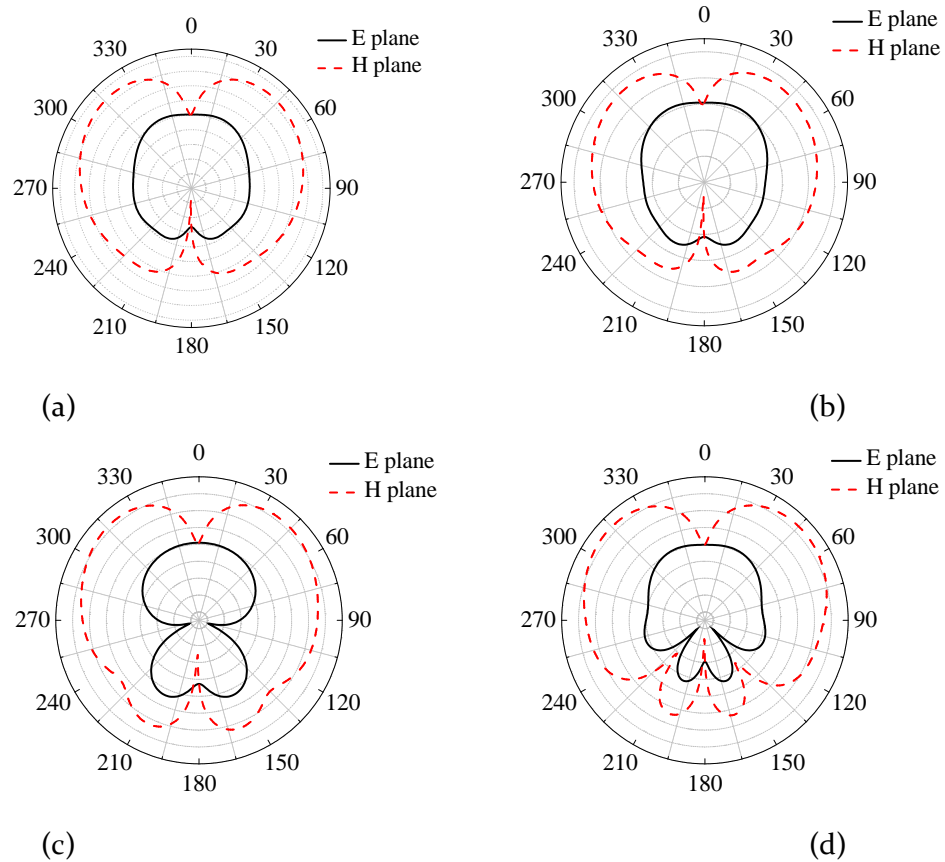


Fig. 5: Radiation pattern on skin with thickness (a) 1mm (b) 2mm (c) 5mm and (d) 10mm.

THE RESULTANT EFFECT OF HUMAN BODY PROXIMITY

The resultant effects of human body proximity can be obtained by combining the effect of skin, fat and muscle, and other related tissues within the body [10-11]. Furthermore, beside differences in weight and size, in other words differences in body mass index and statue among the populace, human body is highly stratified inhomogeneous medium. Even within the same subject, tissues are not evenly distributed to various part of the body. Some parts have high density of particular tissues than others and vice versa. Three layered human body model (skin, fat and muscle with thickness of 2mm, 3mm and 5mm respectively) has been used to approximate the effect of human body proximity to the performance of an antenna for WBAN applications. The results are shown in fig. 6a, fig.6b and fig.7.

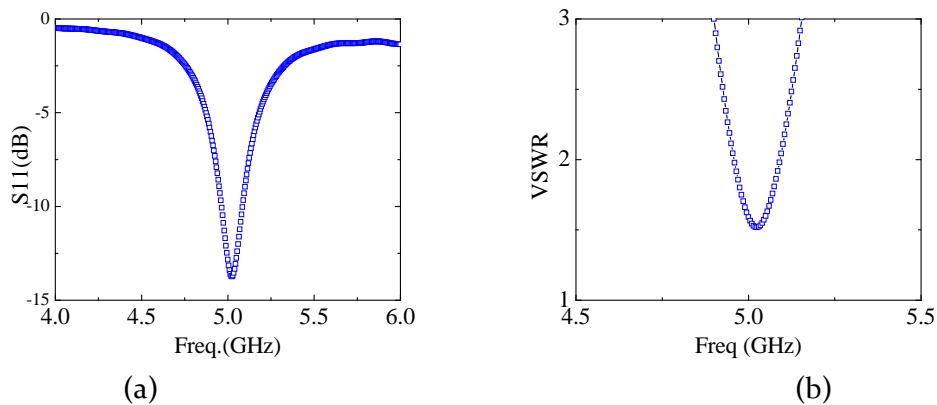


Fig. 6: Simulated antenna on human body model (a) Return loss and (b) VSWR.

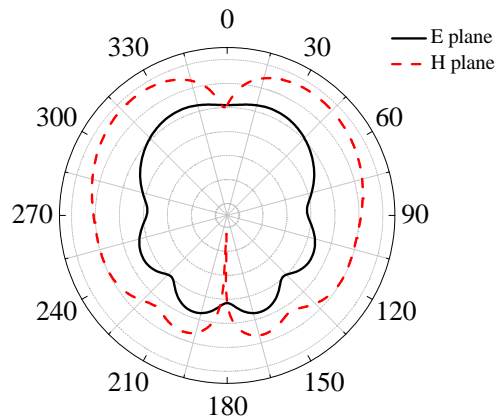


Fig. 7, Radiation pattern of the antenna simulated on human body model.

ANTENNA FABRICATION AND MEASUREMENT

The antenna is fabricated using printed circuit board (PCB) technology on fr-4 substrate, and measured using vector network analyzer. The measured impedance bandwidth covered 4.85GHz to 5.2GHz. Figure 7a presents the fabricated antenna and the measured return loss is presented in figure 7b.

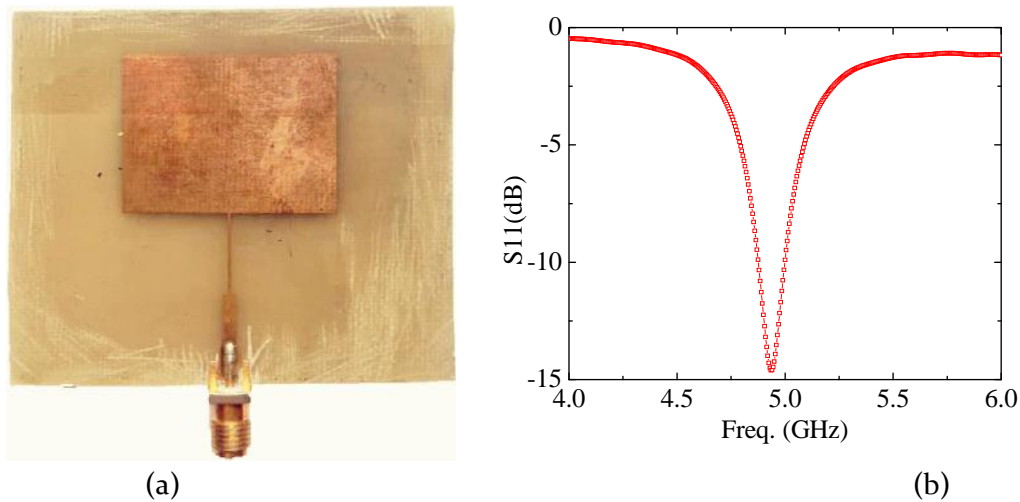


Fig. 7: Fabricated antenna

CONCLUSION

Human body is generally characterized with high dielectric permittivity and low conductivity at microwave frequencies, this make it a hostile environment for the propagation of E.M signals. The effect of human body to the performance of antenna is investigated and it was discovered to have less effect on the resonant frequency but more effect to the radiation pattern. Furthermore, the higher the thickness of human tissue the higher the impact

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