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Radiation evaluation of a wearable antenna on human head in the ISM band

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Abstract
This article presents the effect of electromagnetic waves on a homogenous human head model of an adult exposed to the antenna designed in the ISM2400 band. The objective is to evaluate the specific absorption rate (SAR) due to the propagation of electromagnetic waves along a human head for different antenna transmissions power simulated on the human head at a frequency of 2400MHz. All results, reflection coefficient, VSWR, radiation pattern, SAR and field distributions are presented. The simulation analysis was performed using the CST microwave studio software.

Keywords: WBAN, patch antenna, SAR, human head, CST microwave studio.

INTRODUCTION

The wide application of wireless communication has attracted a lot of concern about safety of wireless devices [1]-[3]. Many investigations have been carried out to determine the effects of radio frequency (RF) radiation on human body using various exposure scenarios and models [1], [4]-[6]. An example of this wireless communication is the WBAN (Wireless Body-Area Network) system which has received widely attention as a promising new wireless communication technology these years. Generally, WBANs are classified into two groups: wearable WBANs and implant WBANs. These wireless network devices on or near a human body area can share the data. Furthermore, specific designed small sensor can transplant into a human body to monitor the health condition. As smaller area network than Bluetooth, it is important to choose a suitable wireless communication technology to make our body health from the electromagnetic wave.

Earlier some countries had recognized the electromagnetic emission harm to human body and set some health standard about the electromagnetic emission. Today the main standard of electromagnetic emission is the generally limited value of radio frequency in the space provided by IEEE [7] and ICNIRP [8]. For evaluating the radio frequency (RF) exposure level, the federal communications commission (FCC) recommends to measure a specific absorption ratio (SAR) in [9], which corresponds to an absorbed energy resulting into a temperature elevation of a specific tissue through the radio propagation.

In this paper, we describe a study of the electromagnetic absorption in the human head for a microstrip patch antenna and compare the mass normalized rates of energy absorption (specific absorption rates or SAR's) with the RF Safety Guidelines [10].

The remaining of this paper is organized as follows. Section 2 presents the antenna geometry used in this study. Section 3 investigates the performance parameters of the patch antenna. The section 4 discuss the simulations results. Finally, Section 5 shows the results obtained for specific absorption rate on the spherical homogenous model with the three different antenna powers.

ANTENNA GEOMETRY

The proposed patch antenna consists of patch, and substrate as shown in Fig. 1. The dimension of FR-4 substrate used board is 46.6 mm (width) x 38 mm (length), thickness of 1.6 mm and dielectric constant (εr) of 4.7. The rectangular patch thickness (PEC) is 0.035 mm. The antenna is fed by a microstrip line. Then, the design had been simulated using CST Microwave Studio simulation software.

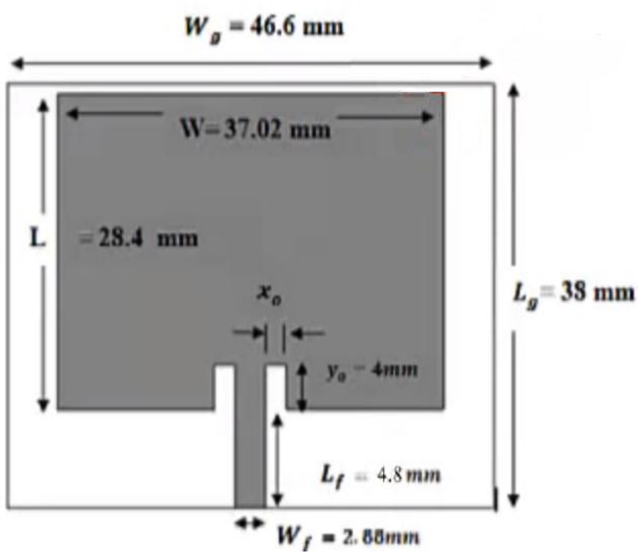

Fig.1.Geometry of the patch antenna

PERFORMANCE PARAMETERS

Following are some of the performance parameters used to measure the performance of microstrip patch antennas [11].

A.Radiation pattern

It is radiation properties of the antenna as a function of space coordinates. Radiation pattern is determined in a far field region and is depicted as a function of directional characteristics.

B.Directivity

It measures how directional an antenna's radiation pattern is. Antenna that radiates equally in all directions would have directionality equal to 0, and directivity if this type of antenna would be 1(0 dB). Directivity is a function of angle; however the angular variation is described by its radiation pattern.

C.Gain

It is closely related to the directivity, it takes into account the efficiency of the antenna as well as its directional capabilities. Absolute gain is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained of the power accepted by the antenna.

D.VSWR(voltage standing wave radio)

It is a function of the reflection coefficient which describes the power reflected from the antenna. It is always a real and positive number for antennas. The smaller the VSWR, the better the antenna is matched to the transmission line and more power is delivered to the antenna.

E.Reflexion coefficient(S11)

S11 represents how much power is reflected from the antenna, and hence is known as the reflection coefficient or return loss. If S11=0 dB, then all the power is reflected from the antenna and nothing is radiated.

RESULTS AND DISCUSSION

This section will discuss the important antenna parameter such as return loss, voltage standing wave radio (VSWR), bandwidth, directivity and gain of the patch antenna.

Fig. 2 shows the simulation result for return loss, S11 witch is equal to-11.52dB.The resonant frequency is 2.45GHz. The Fig. 3 shows that the value of VSWR is less than 2dB for the resonance frequency. The maximum gain of proposed antenna across resonant frequency are simulated and shown in Fig. 4. The antenna gain at 2.45GHz is 3.74dB. The 3D radiation pattern of the antenna studied is shown in Fig. 5. It's almost omnidirectional allowing use of this antenna for applications in the ISM2450 band.

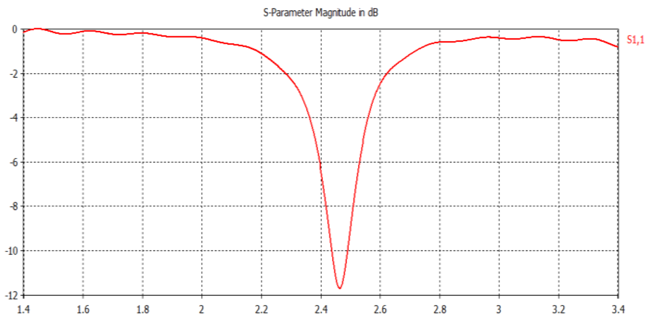

Fig.2.S11 parameter of the patch antenna

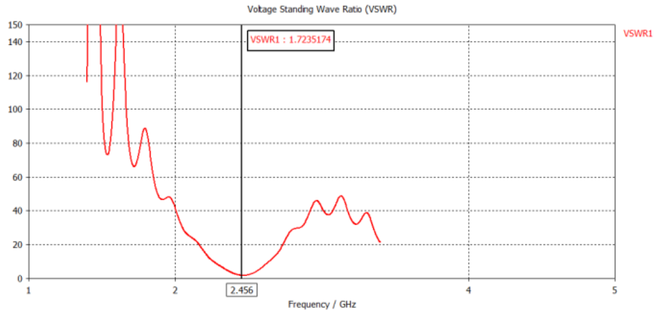

Fig.3.VSWR of the patch antenna

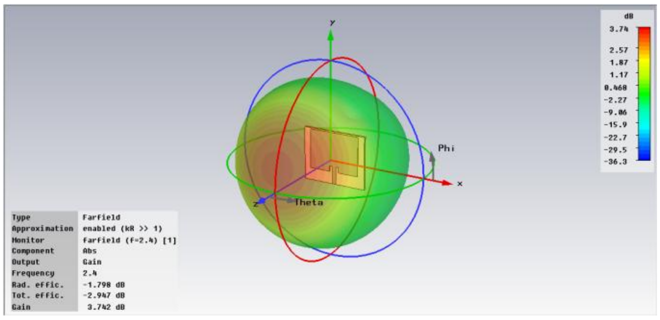

Fig.4.Gain of the patch antenna

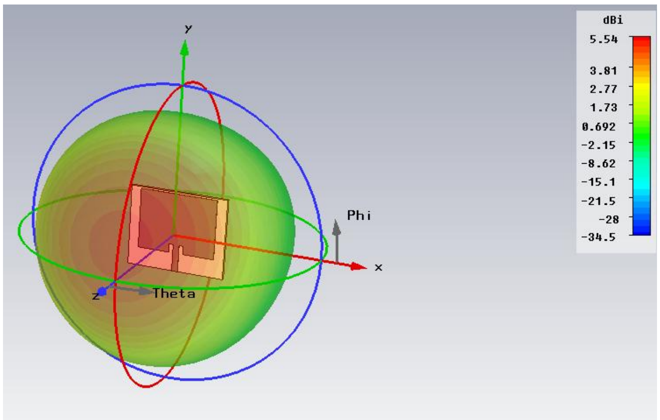

Fig.5.3D radiation pattern

DOSIMETRY

A.Methods and model

The FCC has adopted limits for safe exposure to radiofrequency (RF) energy. These limits are given in terms of a unit referred to as the Specific Absorption Rate (SAR), which is a measure of the amount of radio frequency energy absorbed by human tissue. This measurement is especially important for on/in body applications, which radiate close to or inside the human body known as WBAN applications. The FCC requires devices manufacturers to ensure that their applications comply with these objective limits for safe exposure. The units of SAR are W/kg, or equivalently, mW/g. The SAR is calculated by averaging (or integrating) over a specific volume (typically a 1 gram or 10 gram area). The SAR limit in the US is 1.6 W/kg, averaged over 1 gram of tissue. In Europe, the SAR limit is 2.0 W/kg averaged over 10 grams of tissue [12]. These maximum SAR should not be

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exceeded to avoid health hazards. The specific absorption rate is described by the following equation:

$$SAR=\frac{1}{2}\cdot\frac{\sigma}{\rho}|E|^2 \qquad (1)$$

Where σ is electric conductivity (S/m) and ρ is the tissue density (kg/m3).

In this study, we will evaluate the effects induced by the patch antenna located on human head in term of SAR. The Fig 6 shows the spherical model of the human head and the antenna position. It's a spherical homogenous model which consists of one layer of skin and has a radius of 90 mm.

The propagation depends on the dielectric properties of the layer, density and wavelength.

Table 1 gives the values of skin property for the 2400MHz frequency [13].

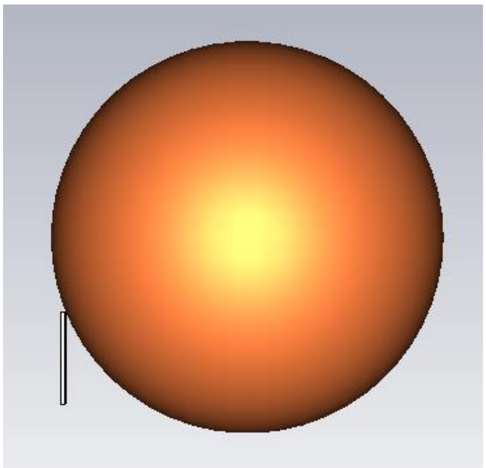

Fig.6.human head model and antenna position

TABLE.1.The dielectric properties of skin at 2400MHZ

Tissue	ε_r	$\sigma(S/m)$	$\rho(*10^3 Kg/m^3)$
Skin	38.0629	1.4408	1.01

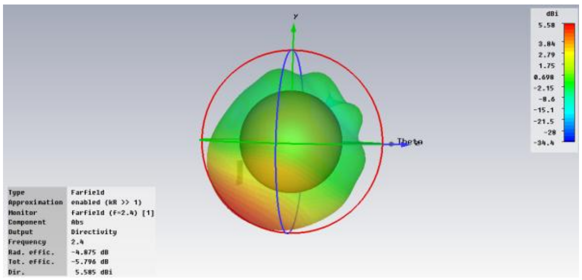

Fig.7.3D radiation pattern of the patch antenna on the human head

B.Specific absorption rate

The Fig 7 shows the results obtained for specific absorption rate on the spherical homogenous model with three different antenna power 0.1W [14], 0.12W [15] and 1W [16] at 2450 MHz. The results allowed us to conclude that more the antenna power is high, more than the SAR reached high values and vice versa. Thus, from Fig 8 and 9 the penetration of specific absorption rate in tissues does not exceed the standards set by IEEE and FCC namely 2W/kg. But if the antenna power is more than 0.12 W there is an over absorption. For example for Fig10 (antenna with a power of 1W), we note that the SAR has exceeded the allowed SAR value.

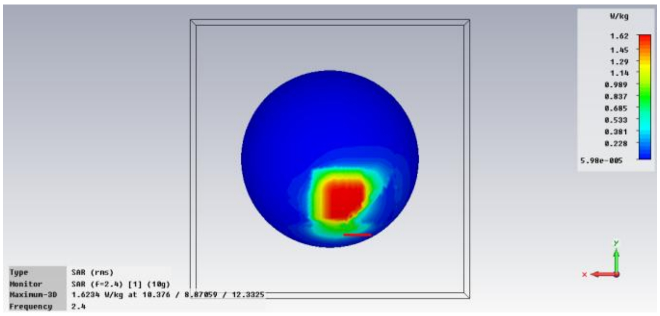

Fig.8.SAR value for antenna power of 0.1W

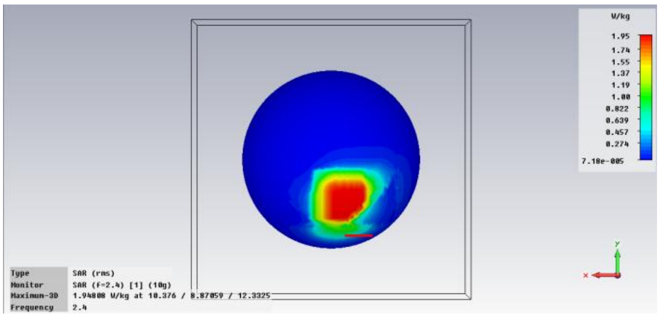

Fig.9.SAR value for antenna power of 0.12W

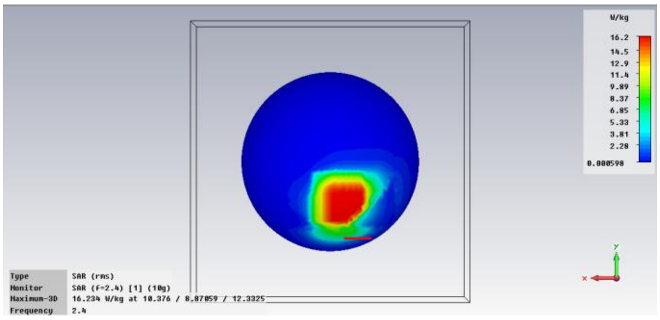

Fig.10.SAR value for antenna power of 1W

Conclusion

A patch on-body antenna for WBAN applications has been simulated and measured .The bandwidth was sufficient to cover the required frequency bands (2.4 GHz) ISM band. The antenna provides an omnidirectional radiation pattern for on body communication in the 2.4 GHz ISM band. To verify these properties, a homogenous human head for 2.4 GHz was fabricated and used to measure the antenna performance. SAR measurement was conducted to investigate the effect of electromagnetic wave on human head absorption. We have demonstrated that the proposed antenna can be effectively deployed on a human head to allow WBAN applications if the antenna power transmission is under a limit of 120mW.

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