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Investigation of a Wearable Textile Monopole Antenna on Specific Absorption Rate at 2.45 GHz

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Abstract**—**This paper discusses the investigation of a wearable textile monopole antenna on specific absorption rate (SAR) for body-centric wireless communication applications at 2.45 GHz. The antenna is characterized on a realistic 8 x 8 x 8 mm^3 resolution truncated Hugo body model in CST Microwave Studio software. The result exhibited that the simulated SAR values were reduced significantly by 83.5% as the position of textile monopole was varying between 0 mm and 15 mm away from the human upper arm. A power absorption reduction of 52.2% was also noticed as the distance of textile monopole increased.

Keywords**—**Monopole antenna, specific absorption rate, textile antenna.

I. Introduction

WEARABLE computing system has gained a lot of attention as it becomes evident that many devices are used in a close proximity or contact of human body nowadays, including watch phone, wearable computing devices, RFID and health care, military and monitoring devices [1-9]. One of the most important features for body-centric communications, which is antennas, has now become a significant research area due to the increasing demands of electronic devices used on the body [3]. Antennas are designed for three different types of operation namely antennas for off-body links, on-body channels and in-body links [3-4]. Antennas for off-body links is known as the antennas which operate in the presence of human body with outward radiation from the body. Meanwhile, the on-body channel provides the support links from one part of the body to another. The antenna for in-body links are used for medical implant [3].

A promising candidate of wearable antenna structures to be used for body-centric communications is the textile antenna. Recently, this antenna has received growing interest due to its flexibility to be integrated into clothing. This has raised an alert of health risks from electromagnetic fields as the textile antenna is specifically designed to be operated in close proximity of human body. Hence, the SAR is utilized in order to address the health risks imposed by wearable communication devices to the human body. Most of the international exposure standards and guidelines use the SAR as a dosimetric quantity for frequencies up to 10GHz [2].

SAR is a crucial parameter to measure the amount of electromagnetic field absorbed by human tissues. The electric field intensity level, E in volts per meter represents a directly measurable exposure parameter corresponding to a basic restriction [11]. SAR is formulated as follows,

$$SAR = \frac{\sigma |E|^2}{\rho} \tag{1}$$

where $|E|$ is the root means square (rms) value of induced electric field (V/m), σ is the electrical conductivity of the tissue in Siemens per meter (S/m) and ρ is the density of the tissue in kilogram per cubic meter (kg/m^3). The SAR unit is in watts per kilogram (W/kg). The International Commission on Non-Ionizing Radiation Protection (ICNIRP) and ANSI/IEEE for the United States establish the SAR limits for hands which is equal to 4 W/kg (over a volume of 10g) for this operation range [2].

As the wearable textile monopole antenna is to be mounted and operated in the vicinity of human body, it is imperative for the proposed antenna to be assessed in terms of SAR values. The antenna placed on-body also has to have a reduced SAR values [3]. In [2, 12-15] several textile antennas for wireless local area network (WLAN), wireless body area network (WBAN) Zigbee and Bluetooth applications were studied, however, very few papers [2], [12], investigated the SAR of the antenna mounted on the human body. [2, 12-15] mainly focused on the design of textile antenna with full ground plane. None of these papers discusses the SAR of textile antenna for partial ground. Therefore this paper is aimed to investigate the effect of SAR values of the wearable textile monopole antenna with partial ground plane by varying the location of the textile monopole away from human body. The delivered power is 1W. Hugo body model using CST Microwave Studio software is utilized to demonstrate this effect.

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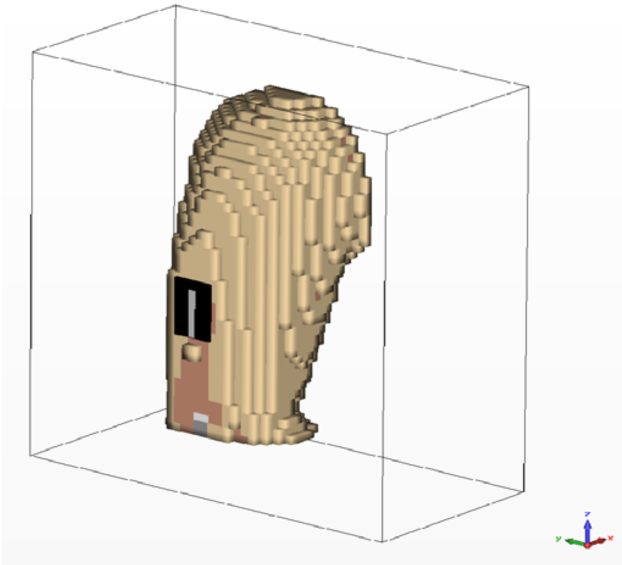


Fig. 1 Simulation for a wearable textile monopole antenna placed on human upper arm

II. Antenna Mounted on Human Upper Arm

The design of monopole antenna is presented in [16]. This wearable textile monopole operates at 2.45 GHz where ShieldIt Super as conducting element and felt fabric as substrate element are used. The textile monopole is mounted on human upper arm as this location is suitable to be implemented in real-life. The antenna is simulated in the proximity of a truncated HUGO voxel model in CST Microwave Studio software to reduce computational time. Its cell size is 8 mm by 8 mm by 8 mm. Hugo model is a voxel data set based on the Visible Human Data Set, produced by National Library of Medicine, Maryland [17]. 1W delivered power gives SAR distribution. Fig. 1 illustrates the selected part of the body mounts the antenna in HUGO voxel model simulation with the dimension and location of the textile monopole. The Hugo model upper arm is truncated so as to reduce the computational resource. A global number of 10 lines per wavelength with subgridding were set in the mesh settings. Hexahedral Fast Perfect Boundary Approximation (FPBA) mesh technology was selected in this simulation.

III. Results and Analysis

Fig. 2 showed 10g SAR is plotted as a function of distance between textile monopole and the human body. It is seen that there was a significant reduce in the SAR values of on-body textile monopole mounted on human upper arm by 83.5% as the distance of textile monopole was increased from human upper arm. The highest SAR was obtained when the textile monopole was mounted on the human upper arm, while the least SAR was at a 15-mm away from the human upper arm. However, the least SAR obtained is still higher than the regulated SAR limit. Due to the absence of a full ground plane in the textile monopole, the antenna's radiation was affected as the antenna pointed backward and towards the human body.

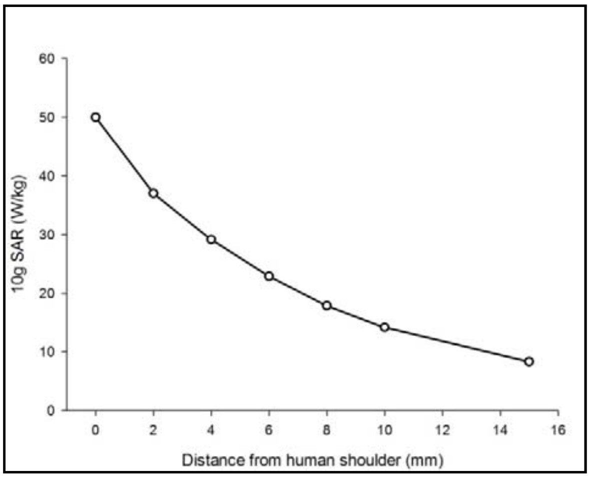


Fig. 2 10g SAR as a function of distance

Therefore, more radio wave was absorbed in the human body. This is also seen evident in Fig. 3 where more power was absorbed when the antenna was placed closer to the human body. Thus, it is recommended that the wearable textile monopole antenna is placed at more than 15 mm away from the human body.

In Fig. 3, it was also observed that, the absorption power was reduced by 52.2% as the distance of textile monopole was placed away from human upper arm. At higher frequencies, the penetration depth is lower, however, because of the presence of lossy human body tissues, the power losses increase which resulted in the higher absorption power in the human body.

Fig. 4 showed the simulation result of SAR over a volume of 10g for wearable textile monopole antenna placed on human upper arm at a distance 0 mm, 10 mm and 15 mm away from human upper arm. Fig. 4 also illustrated the coverage of maximum absorption in 3D view on the human upper arm.

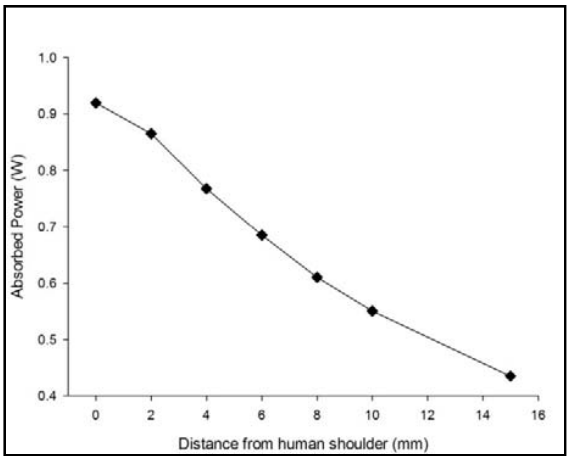
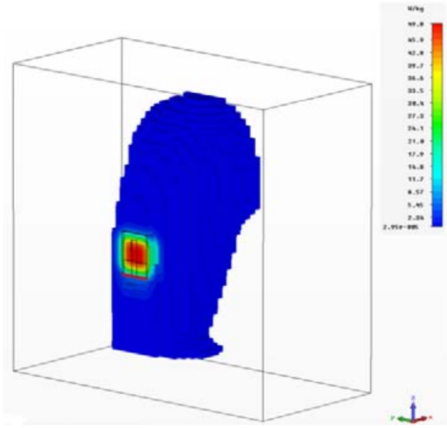
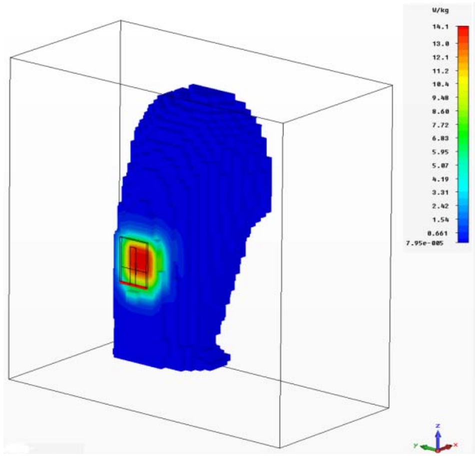


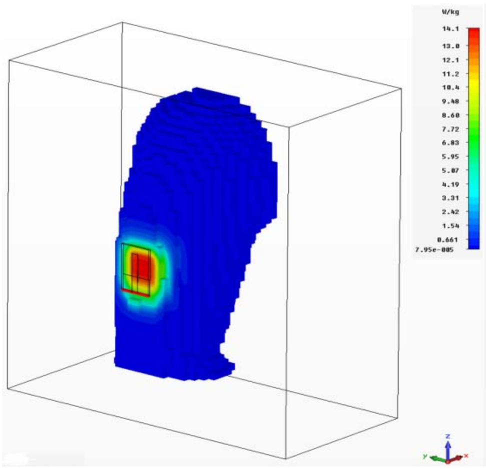
Fig. 3 Absorbed power in watt as a function of distance



(a)



(b)



(c)

Fig. 4 SAR (over a volume of 10g) in 3D view of antenna mounted on human upper arm with distance of (a) 0 mm (b) 10 mm (c) 15 mm

It was noticed that the coverage of maximum absorption of electromagnetic wave, indicating by the red mark, was getting smaller as the distance between textile monopole and human upper arm increased. This also concluded that the effect of electromagnetic wave absorption was reduced as the spacing between the textile monopole and the human body increased.

IV. Conclusion

This paper presents an investigation and characterization of a textile monopole antenna on the SAR designed for body-centric wireless communication applications. Due to the presence of partial ground plane, the SAR results are much higher than the regulated SAR limit. However, the SAR and power absorption drop significantly as the placement of antenna from the human upper arm is increased. For body-centric wireless applications, it is recommended that wearable textile monopole antenna is positioned at more than 15 mm away from the human body to reduce the electromagnetic wave absorption by the human body.

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