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ESTIMATION OF SPECIFIC ABSORPTION RATE IN THE HUMAN LEG AND TESTICLE DUE TO A METALLIC RING

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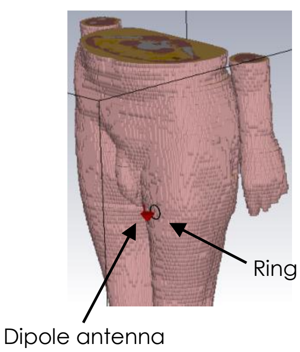
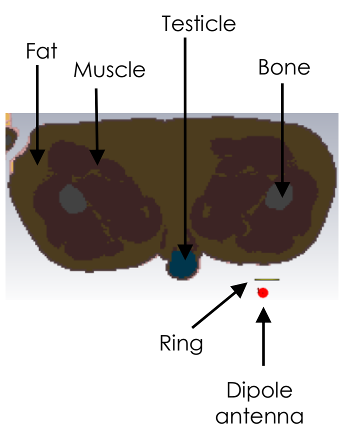
Graphical abstract





Abstract

This research evaluates the effect of human body and metallic ring in the vicinity of dipole antenna on antenna radiation pattern and Specific Absorption Rate (SAR). Homogeneous and realistic body models have been considered in the paper. Half wave dipole antenna is used as the excitation source operating at 0.9 GHz and 1.8 GHz. The metallic ring is modelled as conducting objects. The results have shown that the presence of human body near to the antenna significantly distorted the antenna radiation pattern. The antenna gain is decresed approximately 10 dB at 0.9 GH and 25 dB at 1.8 GHz in the direction of body. Nevertheless, the presence of metallic ring do not have any profound effect on antenna radiation pattern due to their size which is relatively small compared to the size of the human body. Additional metallic ring close to the human leg could alter the SAR and the effect varies depending on the size of the rings. The presence of metallic ring significantly increases the averaged 10g SAR inside the testicle by more than 20% at 1.8 GHz.

Keywords: SAR (Specific Absorption Rate), dipole antenna, antenna performance

Abstrak

Kajian ini mengkaji kesan kehadiran tubuh manusia dan cincin bersifat konduktif yang berhampiran dengan dwi-polar antena pada corak radiasi antena dan Kadar Penyerapan Spesifik (SAR). Model homogen dan model realistik telah digunakan dalam kajian ini. Dwipolar antena digunakan sebagai sumber radiasi pada 0.9 GHz dan 1.8 GHz. Cincin yang bersifat konduktif digunakan dalam simulasi berangka. Keputusan kajian menunjukkan bahawa kehadiran badan manusia berhampiran dengan antena menyebabkan perubahan yang ketara pada corak radiasi antena. Kekuatan radiasi antenna berkurang 10 dB pada 0.9 GHz dan 25 dB pada 1.8 GHz pada arah kehadiran badan. Walau bagaimanapun, kehadiran cincin bersifat konduktif berhampiran dengan antena tidak memberi sebarang kesan kepada corak radiasi antena kerana saiz objek adalah lebih kecil berbanding saiz badan manusia. Kehadiran cincin bersifat konduktif berhampiran kawasan kaki manusia boleh mengubah SAR dan perbezaan kesan bergantung kepada saiz cincin. Kehadiran cincin yang bersifat konductif meningkatkan purata 10g SAR di dalam testikel melebihi 20% pada 1.8 GHz.

Kata kunci: SAR (Kadar Penyerapan Spesifik), antena dwi polar, prestasi antena

1.0 INTRODUCTION

A mobile phone is usually being placed close to the human head when it is in used, while it is left inside the trousers pocket (especially the front trousers pocket) for longer duration when it is not being operated. In this case, the mobile phone is left in standby mode and in very close proximity to the human body (waist area). In 2005, research in [1] has found that 57% of man out of 419 left their mobile phone inside the trousers pocket. This condition has raised the public concerned due to the vicinity of the human sensitive organ to the radiation source. Researches in [2-4] have shown that EM wave could significantly affect the male reproductive system due to the thermal and non-thermal effects especially on human spermatozoa.

In normal practice, there are some conductive metallic items such as coin, ring, zip, and belt being placed inside and in close proximity to the trousers pocket, hence they have become very close to the mobile phone antenna. Besides, numerous studies have examined the interaction between the EM fields radiated by the mobile handset with the human head [5-11], the human head and hand [11-13], and also with additional conductors such as external objects (wire-framed spectacles, braces, ring, bangles, hands-free, earring, zip, coin) [14-19]. However, the effect of EM field on human sensitive organ (testicular) in the presence of any additional metallic objects has received limited attention [20]. Therefore, this research will further investigate the effect of common metallic ring on antenna radiation pattern and the amount of energy absorbed by the body, focusing on the waist area including the testicle tissues.

2.0 Methodology

2.1 Radiation Source

In this paper, two wired dipole operating at 0.9 GHz and 1.8 GHz are used as the radiating source. These frequencies are chosen to represent the frequency for GSM band where the operating devices are used in close proximity to the human body. The dipole antenna is chosen as the radiation source due to its simplicity in the structure and it allows comparison with direct measurement. Figure 1 represents the dimension of the dipole antenna where the length of the antenna is varied depending on the respective frequency used in this research. Dipole antenna is chosen due to its simplicity in structure. The dipole antenna is fed at its center with 50Ω impedance as labeled in Figure 1 as excitation port.

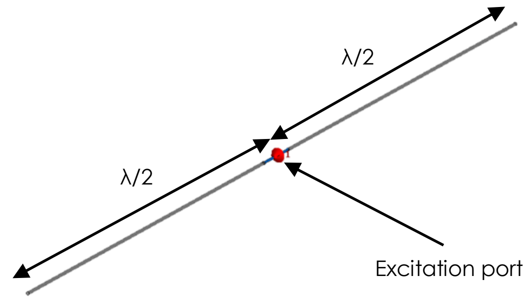


Figure 1 Half-wave dipole antenna

2.2 Body Model

In order to investigate the effect of metallic ring on SAR in the human leg and testicle, two types of body model are used in this paper. They are simple cylindrical homogeneous body model and heterogeneous Voxel body model. Both body models are shown in Figure 2. The cylindrical homogeneous body model is filled with the dielectric properties of muscle equivalent liquid at 0.9 GHz and 1.8 GHz as shown in Table 1. This homogeneous body model is used in the simulation to estimate the SAR for worst case condition. Besides that, SAR validation is less practical using real human body as an object during the experiment and also inhomogeneous body phantom is not yet available in the market.

The Voxel body model is provided by CST Microwave Studio. This body model represents the actual anatomy of human body. The dielectric properties of the human body tissue considered in this paper are recommended by the Federal Communications Commission (FCC) [21].

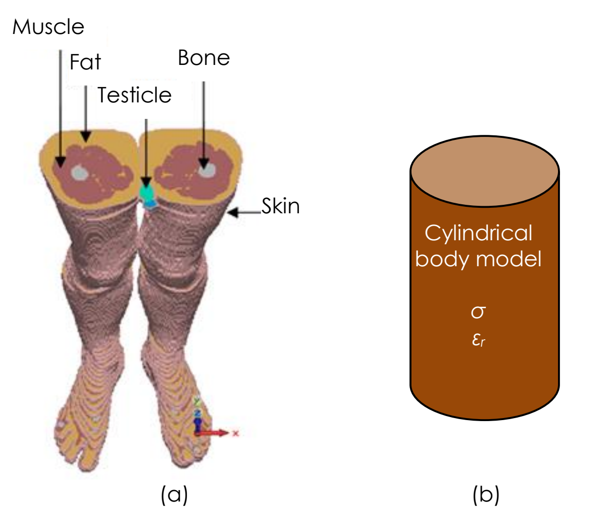


Figure 2 (a) Heterogeneous body model at waist area (b) cylindrical body

Table 1 The dielectric properties of average muscle used for homogeneous body model

Frequency (GHz)	Conductivity, *σ (S/m)*	Relative permittivity, ε_r	Density, *ρ (kg/m)*
0.9	0.97	55.96	1040
1.8	1.39	54.44	1040

2.3 Metallic Ring

In order to investigate the effect of metallic objects and SAR, metallic ring is used in this paper to represent keychain ring that is usually found in the trousers pocket. The metallic ring is chosen due to its position which is near to the mobile phone when the mobile phone is left in the pocket. The size of the ring is chosen to coincide with the size of the actual object and designed as copper with *r* = 10 mm. Figure 3 illustrates the dimension of the ring considered in this paper.

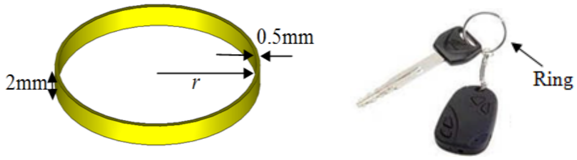


Figure 3 Metallic ring

3.0 RESULTS AND DISCUSSION

3.1 Antenna Radiation Pattern and Reflection Coefficient

Firstly, the cylindrical and Voxel body model is simulated with the λ/2 dipole antenna in free space. The body model is placed at 5 mm away from the antenna feed point. The metallic ring is then introduced in the simulation. The metallic ring is position 1 mm away from the body as the smallest distance considering the thickness of the trousers and also the air gap. The simulation setup for cylindrical and Voxel body model are shown in Figure 4 and ***Figure 5*** respectively. All simulations are executed by CST Microwave Studio. The antenna input power is normalized to 1W for both frequencies.

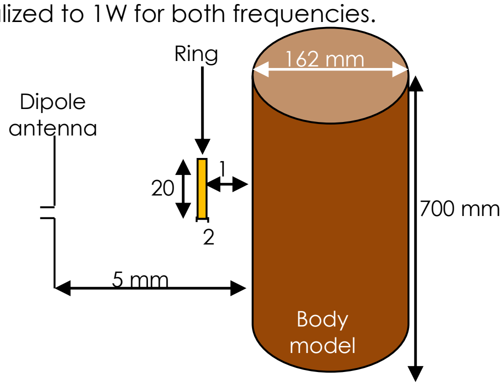


Figure 4 Simulation setup of dipole antenna in the presence of cylindrical body model and metallic ring

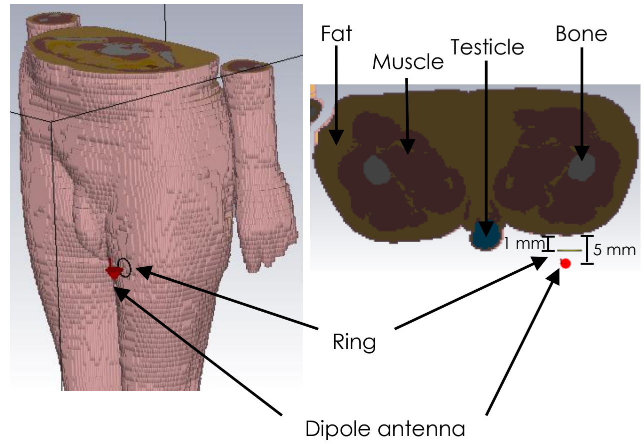


Figure 5 Simulation setup of dipole antenna in the presence of Voxel body model and metallic ring

The effects of two different body model and metallic ring on antenna reflection coefficient are shown in Figure 6. The results show that the presence of body close to the radiation source affects the matching impedance between the antenna and the body. Hence, modified the reflection coefficient and shifted the operating frequency. Besides that, the presence of metallic ring close to the antenna has additional effect on the antenna reflection coefficient. The metallic ring increases the antenna reflection coefficient by 35 dB at 1.8 GHz. However,

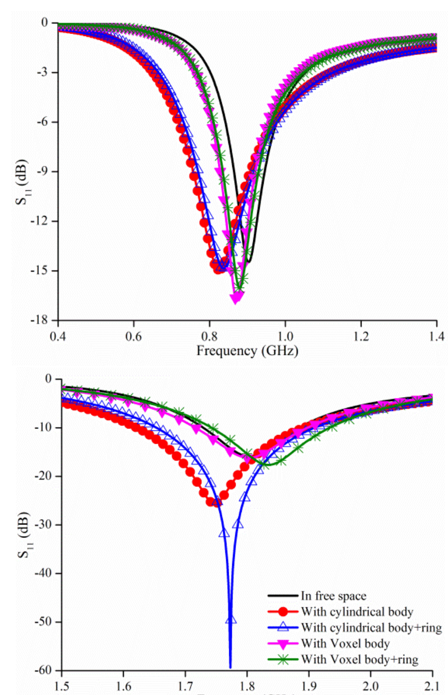
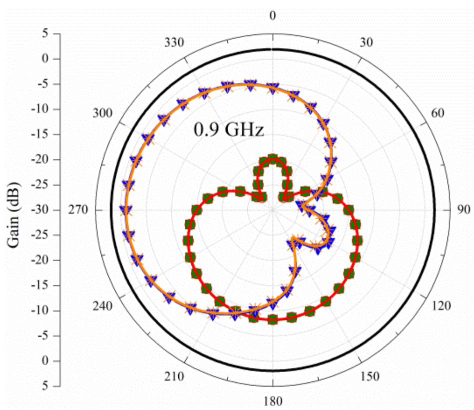
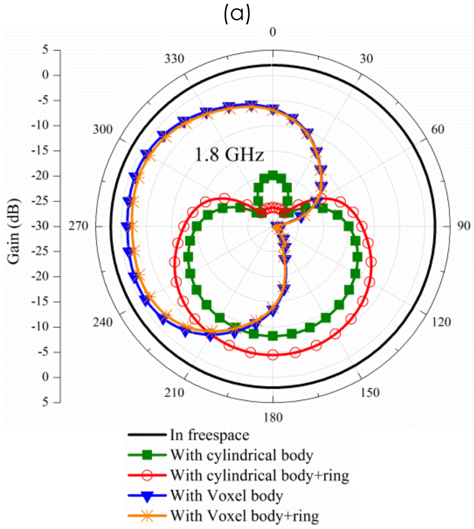


Figure 6 The effect of body model and metallic ring on antenna reflection coefficient at (a) 0.9 GHz and (b) 1.8 GHz

The effects of cylindrical body model and Voxel body model on antenna radiation pattern in the H-plane are shown in Figure 7. The simulated results indicate that the antenna radiation pattern is significantly distorted in the direction of body by approximately 10 dB at 0.9 GH and 25 dB at 1.8 GHz due to the presence of Voxel model. It can be seen that the presence of the ring does not show any important effect on the radiation pattern at 0.9 GHz. This is due to the size of the ring which is much smaller if compared to the size of the body. However, the presence of metallic ring introduced additional effect on the radiation pattern at 1.8 GHz. This is due to the circumference of the metallic ring which approximately λ/4 of the operating frequency. The metallic ring redistributes the current. Thus increase the antenna gain.



(a)



(b)

Figure 7 The effect of ring on antenna radiation pattern at (a) 0.9 GHz and (b) 1.8 GHz using simple cylindrical model body

3.2 10g SAR in the Leg

In this paper, the amount of energy absorbed by the body will be discussed in term of 10g SAR. This is because 10g SAR is considered in standard ICNIRP. Figure 8 shows the 10g SAR in the cylindrical body model with and without the metallic ring. It can be seen that the metallic ring increases the 10g SAR in the simple cylindrical body model. The maximum increment of 28% is observed at 1.8 GHz. This is due to the current induced on the ring, thus the ring acts as the weak radiating source. This results show that the presence of additional metallic object close to the human body could increase the amount of energy absorption in the body.

Besides, different types of body models lead to the variation of the SAR absorption. This is due to the presence of multiple tissue layers with different dielectric properties in Voxel body model compared to the homogeneous cylindrical body model.

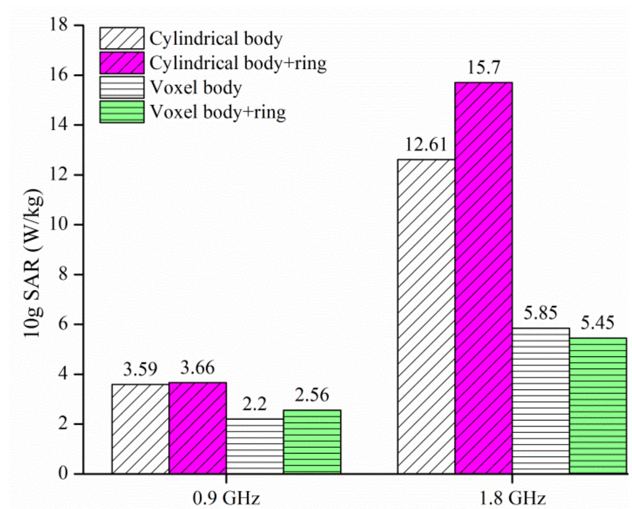
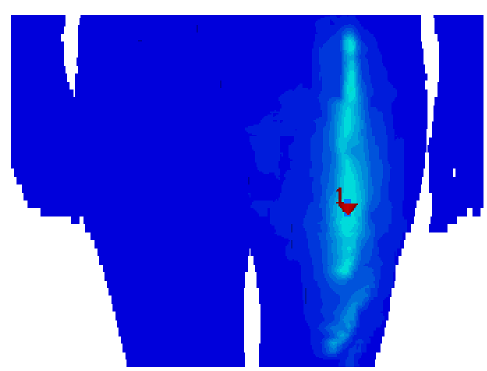


Figure 8 The effect of ring on 10g SAR in the simple cylindrical body model at 0.9 GHz and 1.8 GHz

Figure 9 demonstrates the 10g SAR distributions in the presence of metallic ring at 0.9 GHz and 1.8 GHz. The figure shows that the amount of energy absorption is notably influenced by the presence of additional metallic object in close proximity to the radiating source and human body. It can be seen that the maximum SAR (indicated by the red region) is more focused near the metallic ring. The metallic object when exposed to the EM wave could induce current and reradiate the energy.



(a)

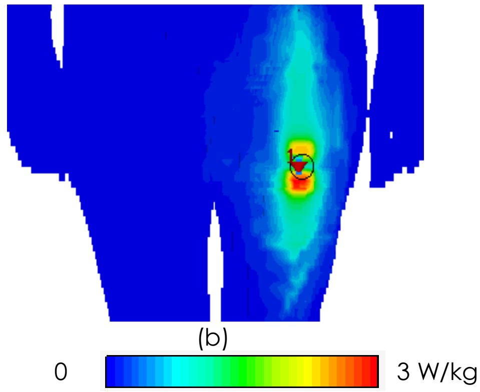


Figure 9 10g SAR distributions for dipole antenna at 0.9 GHz (a) body only (b) with ring

3.2 10g SAR inside Testicle

Figure 10 summarize the 10g SAR calculated inside the testicle. The presence of metallic ring significantly increases the 10g SAR inside the testicle. The maximum of 22% enhancement of 10g SAR is found at 1.8 GHz due to the ring. When the body is exposed to the EM wave, the human biological tissue could absorb the radiated power by the antenna. Thus, leads to the heating effect on human body. The temperature increased in the human biological tissue will disturb the normal behavior of the biological cell [2]. Even small increment in the sensitive organ (testicle) could be more important and a bigger concern. Therefore, it is suggested that, the mobile phone should not be kept inside the trousers pocket together with any additional metallic object which could harm and might affect the human reproductive function [3].

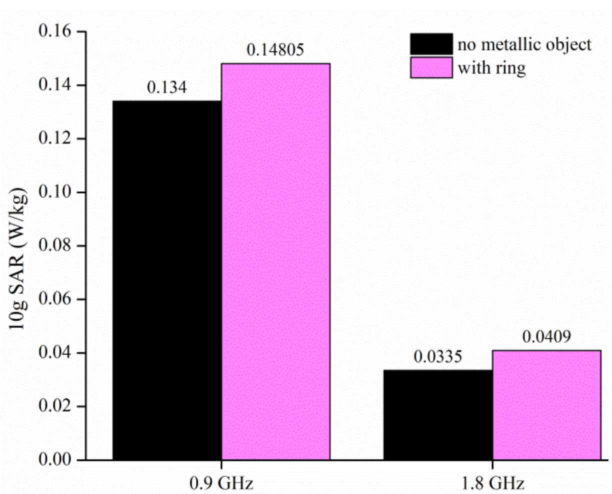


Figure 10 10g SAR inside the testicle with and without the presence of metallic ring at 0.9 GHz and 1.8 GHz for Voxel body model

4.0 CONCLUSION

In this paper, the effect of metallic ring on antenna reflection coefficient, radiation pattern and SAR has been evaluated. The presence of body significantly distorted the antenna radiation pattern. This is due to the blocking effect and a radiated power is absorbed by the biological tissue. Besides that, the small size of metallic ring when added in between the radiation source and the body only produces a very minor different on the antenna radiation pattern when compare to the effect produce by the body only. It is suggested that, the size of the metallic object which is relatively small compared to the wavelength do not prominently affect the radiation pattern.

Additional metallic ring in close proximity to the radiating source could modify the SAR distributions and the amount of energy absorbed by the body tissue. Based on the results presented in this paper, it can be concluded that having an additional metallic ring close to the radiation source could enhanced the amount of energy absorption by the human tissue. Metallic ring possibly enhance the SAR absorption inside the testicle by more than 20%. The increment of SAR is directly proportional to the increment of temperature in the adjacent tissue. Therefore, the presence of metallic ring could cause burn accident in the adjacent tissue [3].

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