A STUDY ON THE EFFECT OF LOOP-LIKE JEWELLERY ITEMS WORN ON HUMAN HAND ON SPECIFIC ABSORPTION RATE (SAR) AT 1900 MHZ

N. A. Samsuri, J. A. Flint

Department of Electronics and Electrical Engineering
Loughborough University, United Kingdom
Email: N.A.Samsuri@lboro.ac.uk, J.A.Flint@lboro.ac.uk

Abstract: This paper presents simulation results that evaluate the effect of loop-like jewellery items (rings and bangles) worn on human fingers and wrist on SAR in the human head and the hand. The jewellery items were modelled as conducting objects with the typical commercial sizes available. Rings were placed on different fingers in a computer model for comparison purposes. The amount of energy absorbed in the head/hand and the effect brought about by the jewellery are shown to vary for different antennas. In this study, a monopole and a PIFA antenna have been employed. The results obtained indicated that: (i) by using a monopole antenna, the peak and average 1g SAR in the head are slightly decreased by the introduction of the ring and bangle, (ii) by using a PIFA, the peak and average 1g SAR in the head are increase by more than 12% and 11% respectively by the metallic rings.

1. Introduction

The use of mobile phones is increasing day by day and yet at the same time the user has become concerned about possible health effects due to the electromagnetic field radiated by the antenna. Conventionally, the mobile handset is placed very close to the head and partially masked by the human fingers where a certain amount of electromagnetic energy passes through the head and the hand rather than being directly radiated. Numerous studies have examined the interaction between the electromagnetic fields radiated by the mobile handset, the human head, the hand [1-4], additional conductors such as external objects (wire-framed spectacles, hands-free) [5-6] and metallic implants (surgical pins, jewellery) [7-9] that may also have effects on the amount of the electromagnetic field radiated by the antenna. In recent years, a number of studies have focused on the effect of metallic jewellery such as earring worn on the ear [8, 9] and implanted metallic loops and pins inside the head [7]. These investigations found that the metallic earrings, metallic loops and rings could increase the SAR. As the hand is found to give a noticeable effect on the antenna radiation performance and could also modify the SAR distribution in the head [2], the introduction of the metallic ring/bangle worn on the hand is expected to have an additional effect. In order to study the effect brought about by the jewellery rings on SAR, a simplified geometrical representation of the human finger/arm worn the ring/bangle has been presented [10]. The results indicate that the electric-field distribution at the centre of the ring and in between the ring and the dielectric were substantially changed by the dielectric (human finger/arm) inclusion. However, the measurement campaign carried out during this study suggests that there is no significant effect on SAR due to the presence of the small metallic-loop, although a larger loop does cause an increase in 1g and 10g SAR at 1800 MHz. The effect of the loop-like jewellery (worn on the fingers and wrist) on SAR values within the head-hand model in the 900 MHz frequency band has been presented in [11]. This paper will presents simulation results that quantify the effect of loop-like jewellery items worn on a realistic human hand on SAR. This will consider both the head and the hand itself within 1900 MHz frequency band.

2. Description of model

To begin, a very simplified spherical head and a block-hand model were employed for comparison with the more detailed model (Fig. 1(a)). The simple spherical head radius was set to 105.5 mm (as in [9]). Next, a homogeneous SAM head (Fig. 1(b)) and a realistic human hand model were used and numerical simulations were computed using the TLM method. The frequency dependent parameters (ε, σ) used in the human head and the hand were the same as those for the standard tissue equivalent liquids recommended by the IEEE and FCC [12]. The handset was modelled as a metallic box (90×16×44 mm) with a $\lambda/4$ monopole antenna on top of it. The handset unit was placed next to the head in cheek position (Fig.1) and the frequency of excitation was 1915 MHz (the precise λ resonance for the antenna). In order to study the effect of the loop-like jewellery items, rings and

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bangles were modelled as conducting objects with their sizes chosen in order to coincide with the typical sizes available (as in Table 1). All results in this paper are normalized to 125 mW input power.
SAR indicates the amount of RF energy absorbed by the body (per unit mass) when exposed to the electromagnetic field radiation. SAR is calculated by the equation Eq.1:

$$SAR = \frac{\sigma |E|^2}{\rho} \quad \text{(W/kg)} \qquad (1)$$

|E| is the electric field magnitude (rms), σ is the conductivity (S/m) and ρ is the material mass density (kg/m^3).

Table 1: Ring and bangle geometrical representation employed in this study

Item	Location	Inner radius (mm)	Length (mm)	Thick (mm)
Ring i	Index finger	10.5	5	2
Ring m	Middle finger	10.5	5	2
Ring r	Ring finger	9.8	5	2
Bangle	Wrist	33.34	10	3

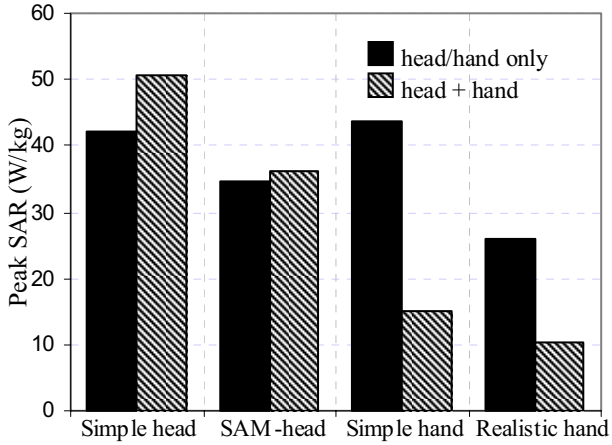

Figure 3: Comparison of the peak SAR in the head and the hand between simple spherical-head and block-hand model with the SAM-head and realistic hand model

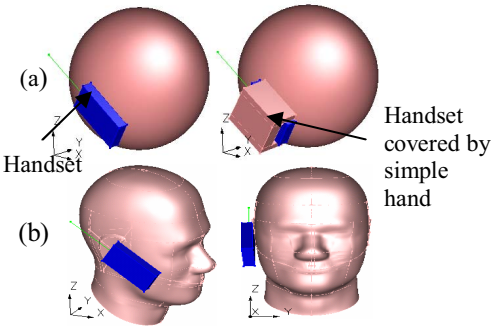

Figure 1: (a) The simplified spherical head and block-hand model, (b) the SAM head model with the mobile handset in cheek position

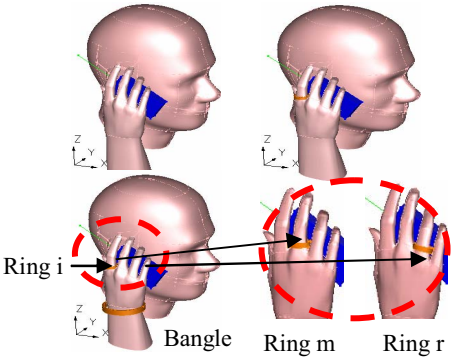

Figure 2: Realistic hand model added to the mobile-SAM head model with the ring in three different position (with or without bangle)

3. Results

a. Simplified spherical-head and block-hand model

Fig. 3 shows the peak SAR in the head and the hand of the simplified head-hand model and the realistic head-hand model. Good agreement was obtained between both models. The peak SAR in the head is increased by the presence of the hand. However, the peak SAR in the hand is decreased quite significantly when place close to the head. Since the simple block-hand model was highly simplified, no effect from the metallic loop could be modelled for comparison with the more detailed head and hand model.

b. Detailed (SAM) head and realistic hand model

Previous research has found that the presence of human hand does alter the SAR values within the head, although quite marginally. Most of the investigations to date have employed a very simple block-hand model that does not include any fingers. In reality the fingers of mobile users frequently stray near to the antenna and it is potentially of great interest to understand what effect this would have on the results. Here a realistic hand

model (with realistic fingers) is employed which allow the ring and bangle to be worn and placed in different positions for comparison. The placement of fingers with rings can therefore be studied as these are likely to have an effect when placed close to the antenna.

The results for the peak and the average 1g SAR in the head and the hand with and without jewellery at 1915 MHz are shown in Fig. 4. The peak and the average 1g SAR in the head are slightly increased (compared to the mobile-head only) when the hand is added to the mobile-head model. This can be explained partly by the reflection at the hand's dielectric boundary. It can be noted that for the same experiment but adding jewellery items to the hand there are only marginally differences in the result. However, if a PIFA antenna is used as the radiating source, there are some significant changes. The peak and the average 1g SAR results for the monopole and the PIFA antenna are summarized in Table 2. The results show that, by using a PIFA, a metallic ring could notably increase the peak SAR in the head and the hand. The ring that worn on middle finger (with bangle) has increased the peak SAR and the average 1g SAR in the head and the hand by more than 12% and 11% respectively.

In addition, the SAR distribution within the hand (for the monopole antenna) is illustrated in Fig. 6. The peak SAR values were found on the closest fingers to the antenna and the handset body when no ring/bangle is present. When the ring is added to the simulation, the maximum SAR distribution values appear to be at the edge of the ring on the particular finger that worn the ring and also to the finger next to it.

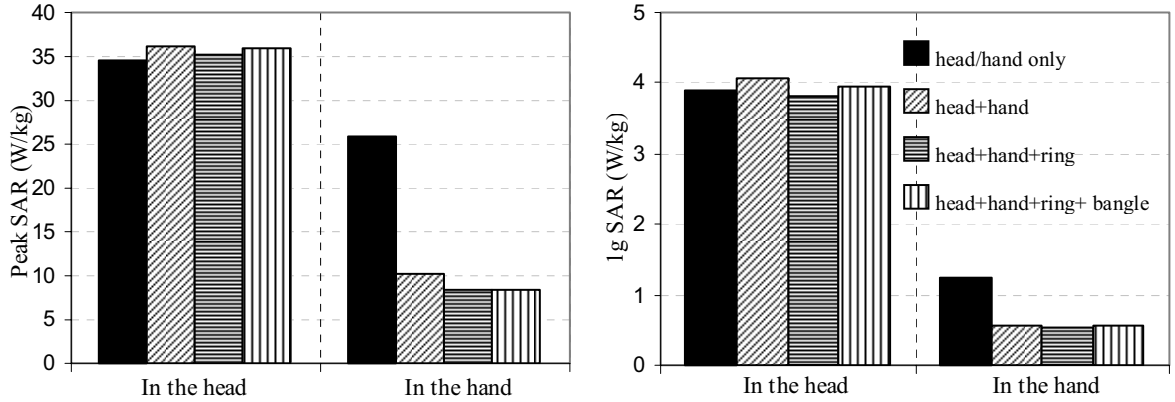

Figure 4: The peak and averaged 1g SAR in the head and the hand, with and without jewellery at 1915 MHz.

Table 2: The peak and the average 1g SAR in the head and the hand for a monopole and a PIFA antenna.

	1915 MHz (monopole)				1915 MHz (PIFA)			
SAR (W/kg)	In the head		In the hand		In the head		In the hand	
	peak	1g	peak	1g	peak	1g	peak	1g
Mobile-head/hand	34.60	3.89	25.99	1.24	5.80	2.04	3.12	0.66
Mobile-head-hand	36.04	4.06	10.27	0.56	7.35	2.02	5.93	0.62
Mobile-head-hand-ring i	35.25	3.80	8.36	0.54	7.73	2.20	6.18	0.65
Mobile-head-hand-ring i-bangle	35.80	3.96	8.38	0.56	8.05	2.19	6.32	0.65
Mobile-head-hand-ring m	34.87	3.77	10.08	0.56	7.79	2.20	6.89	0.68
Mobile-head-hand-ring m-bangle	35.81	3.97	10.06	0.55	8.26	2.32	6.88	0.69

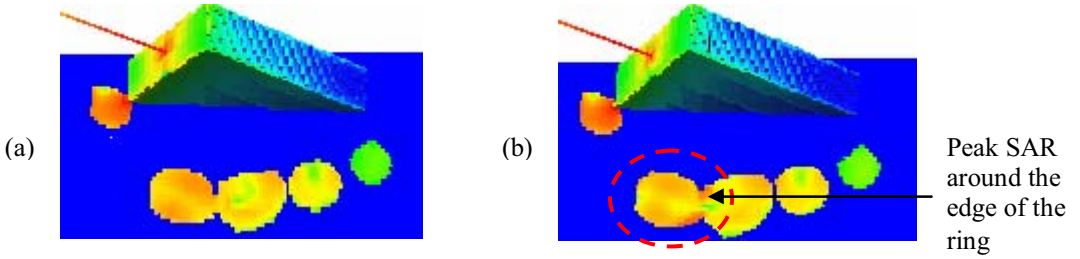

Figure 6: SAR distribution in the hand when (a) no ring, (b) the ring worn on the index finger at 1915 MHz.

4. Discussions and conclusions

The results presented in this paper are based on computer simulation using the TLM method. It is currently difficult to validate the simulation results with the direct measurement of SAR due to the lack of a scannable hand phantom and the inherent difficulty of producing such an item. It is well-known that the hand and head both have an influence on handset antenna performance. This study has indicated that the jewellery worn on human hand has an additional effect, albeit, quite a small one. However, the magnitude of the influence on the result is affected by the proximity of the metallic loop-like jewellery items to the handset antenna and also to the position and geometry of the user's head and hand. The amount of energy absorbed in the head/hand and the effect brought about by the jewellery vary for different antennas. By using a monopole antenna, the introduction of metallic ring has slightly reduced the amount of energy absorbed in the head and the hand. The jewellery worn on human hand has more noticeable effect when utilizing a PIFA as a radiating source. The result also shows that the ring does clearly affect the SAR distribution and hence rings must be considered when measuring SAR. The electromagnetic field radiated from this antenna drives currents more strongly on the surface of the ring and can thus influence local SAR quite significantly. The larger diameter loops found in bangles should be expected to have more significant effect due to their resonant frequency being much closer to the handset operating bands. However, from these results, the bangle appears not to be so important due to the fact that the position of the bangle is far away from the unit antenna or even to the mobile-head model. In addition, it should be noted that there is a general trend for higher frequency communication devices and the influence of jewellery may be more significant due to resonance effects.

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5. References

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