Smart Sticker Including Split Square Rings for Adapting Mobile Phone Radiation Pattern to Lower SAR

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***Abstract* — A Split Square Rings (SSR) based on a sticker is presented to modify the direction of mobile phone radiation pattern. This smart sticker permits the radiation from the antenna of a phone to steer away from the user head. The presented smart sticker is designed for 5 GHz WiFi band (IEEE 802.11ac) for VOIP (Voice Over Internet Protocol) and data applications. It is observed that the smart sticker reduces the peak SAR (Specific Absorption Rate) value averaged over 10g of human head tissues from 2.11 W/kg to a safety value of 1.46 W/kg (a reduction of over 30%).**

***Index Terms* — Split square ring (SSR), specific absorption rate (SAR), radiation pattern, total Radiated power (TRP), mobile phones**

I. Introduction

The use of the mobile phones has grown rapidly in the global communities over the last few years. By 2020, there will be 5.5 billion mobile users [1]. As the usage of the mobile phone is increased, public concern over the effects of Electromagnetic (EM) radiation on human health has gained interest in research communities. Specific Absorption Rate (SAR) is a defined parameter for evaluating EM power absorption by human tissues. The higher the SAR the more radiation is absorbed by the human body. Extremely high value of SAR can cause severe damage to the human body. In more than 80 countries the SAR limit is set to 2.0 W/kg in 10 g of tissue according to the recommendations made by the International Commission on Non-Ionising Radiation Protection (ICNIRP) Guidelines [2]. A large number of research [3]- [5] has been on reducing the mobile phone SAR without compromising the device performance. However, a large separation distance between the shielding material and antenna is required to effectively reduce SAR, which is not suitable for modern slim mobile phones.

To overcome this limitation, an extremely low-profile planar smart sticker containing three SSRs has been proposed and investigated for reducing the SAR in 5GHz WiFi frequency band (IEEE-802.11ac). The smart sticker can be attached to the phone case at the back side of the phone. The smart sticker enables the radiation from the phone antenna to be directed away from the human head during a VOIP call. Thus, the smart sticker empowers the handset to reduce the exposure of human head to EM radiation, lowering the SAR. In this paper, to validate the performance of the smart sticker, a dipole antenna along with the plastic body-frame of a mobile phone and a plastic case are designed to simulate the characteristics of commercially available mobile phones at 5 GHz.

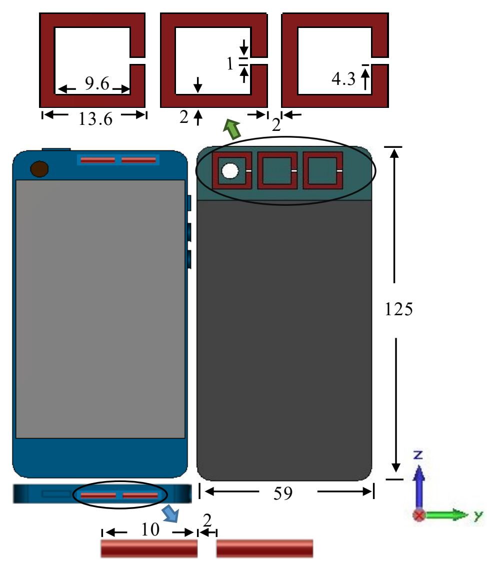

Fig. 1. Top and back view of a phone housing model together with the plastic case showing the dipole antenna and SSR based smart sticker.

II. Configuration of Smart Sticker

Fig. 1 shows the configuration of the smart sticker including three Split Square Rings (SSRs). The SSR has four conducting arms and each having a length of 13.6 mm and a track width of 2 mm. An air gap having a length of 1 mm is inserted in an arm ('+y' direction) of each SSR. Two neighboring SSRs are separated by a distance of 2 mm. The SSRs are printed on the top of a water-resistant paper (with permittivity εr=2.31) having an area of 58 mm×20 mm and a thickness of 0.1 mm. Those areas of the paper covering the camera lens and microphone are cut-away for obvious reasons. A layer of adhesive (εr=3.5) having a thickness of 20 µm is attached on the bottom side of the paper which enable the sticker to stick to any commercially available mobile phone plastic case.

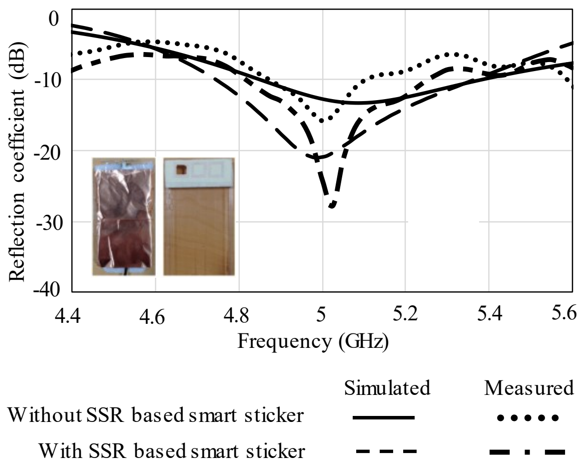

Fig. 2. Reflection coefficient of the antenna together with the phone housing and plastic case, (a) without the smart sticker (b) with the smart sticker.

To investigate the performance of the smart sticker while stuck to mobile phones, a plastic phone case and a phone body-frame are designed as shown in Fig. 1. The plastic body-frame (with εr=2.5 and conductivity σ= 0.02 S/m) has dimensions of 124 mm×59 mm×7 mm. In mobile phones, the back side of the LCD screen is covered by a metal sheet. Hence, the front side of the body-frame designated for the screen is covered by a metal sheet to replicate the effects of the LCD screen, as closely as possible. The metal sheet has an area of 90 mm× 52 mm. The back side of the body-frame is also covered by a metal sheet having an area of 98 mm× 57 mm. A dipole antenna is placed in the metal exposed part at the top end of the body-frame. Each arm of the dipole has a length of 10 mm and two arms are separated by a distance of 2 mm. The antenna is fed by a 100 mm long coaxial cable having a loss of 0.4 dB.

III. RESULTS

Fig. 2 shows the reflection coefficient of the dipole antenna integrated with the complete body-frame and the plastic case attached. The antenna resonates at 5 GHz WiFi frequency and exhibits a reflection coefficient bandwidth (<-10 dB) of 540 MHz (4.84 GHz-5.38 GHz). When the smart sticker is applied on the top end of the case where the antenna is placed, the SSR layer provides a better impedance match for the dipole. Thus, the SSR layers enables the antenna to be more efficient in the 5 GHz band, providing a reflection coefficient bandwidth of 630 MHz (4.72 GHz-5.35 GHz) as shown in the Fig. 2. The measured results are in good agreement with the simulated results.

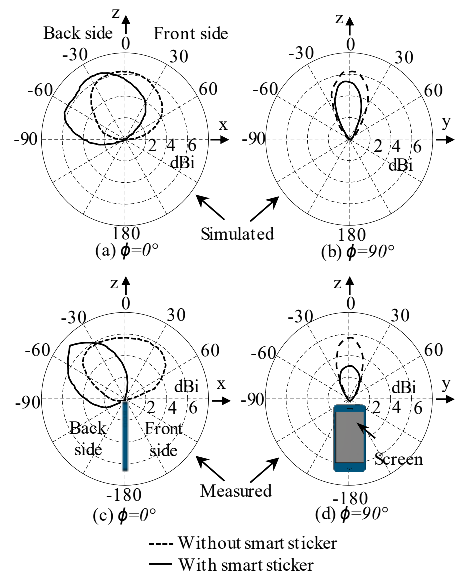

Fig. 3. Polar cut of the radiation pattern; (a) and (b) simulated (c) and (d) measured.

Without sticker the dipole antenna together with the phone body-frame and plastic case provides an almost equal radiation in front and back side of the phone as shown in Fig. 3. The antenna exhibits a maximum gain of 6.31 dBi in the zenith; i.e. θ_{max}=0° with a radiation efficiency of 94.5%. The Total Radiated power is found to be 29.74 dBm. However, when the smart sticker is applied to the case, the EM fields couple to the SSRs causing the radiation to be tilted more towards the backside of the phone, Fig. 3. The maximum radiation occurs in the direction of θ_{max}=-30°. The antenna provides a maximum gain of 6.49 dBi and a radiation efficiency of 98.3%. The TRP is observed to be 29.96 dBm. As Fig. 3 (a) shows the radiation in the front side of the phone is reduced significantly without affecting the TRP.

IV. REDUCTION OF SAR

To investigate the amount of radiation reduction in the front side of the phone an experimental setup was arranged as shown in Fig. 4. In this set-up the dipole antenna inside the phone model is fed from a signal generator which transmits a Continuous Wave (CW) at 5 GHz. The transmit signal strength is selected to be 20 dBm (100 mW). The phone is placed over a sponge platform which is positioned on top a horn antenna. It ensures that front side of the phone always face toward the horn antenna.

The horn antenna is placed inside the SATIMO starlab system and its open-ended mouth is facing upward. The RF-absorbers of the starlab system absorbs all the radiation signals from the back side of the phone. Consequently, the Horn antenna only receive the front side radiation signals and the received signal strength is measured using a spectrum analyzer. It is found that without the smart sticker the phone model radiates -15.72 dBm in the front side as shown in Fig. 5(a). However, with the smart sticker the phone housing assembly radiates only -28.19 dBm in the front side. Therefore, the application of smart sticker enables the phone model to reduce the front side radiation by over 12 dB. Due to the reduction of front side radiation the SAR value of the human head is also reduced.

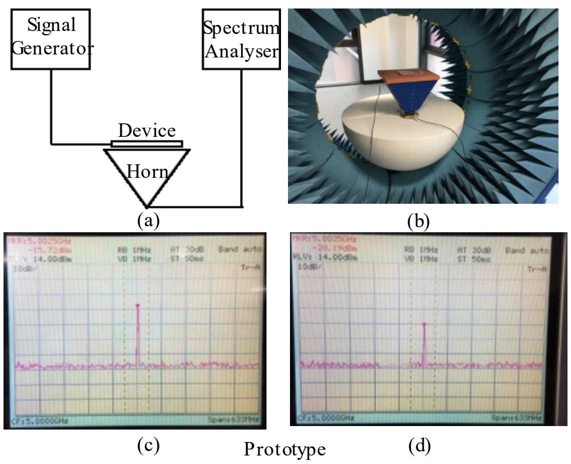

Fig. 4. (a) Experimental setup, (b) horn antenna is placed inside the SATIMO starlab system, (c) Signal strength received by horn antenna without the smart sticker, and (d) received signal strength with the smart sticker.

Fig. 5 shows the simulated SAR distribution on the human head model at the operating frequencies of 5 GHz. A phantom model having accurate shape, size and material properties according to the IEEE/ANSI C95.1 standards is used as human head model. The 2nd order dispersive model for the relative permittivity (outer shell: ε_r=5, inside region: ε_r=42) and the liquid density of 1000 kg/m^3 are specified for the head model. Fig. 5 (a) shows the position of the phone in the vicinity of the human head. The phone model is placed such that its front side touches the ear and the phone is tilted by 45° towards the face from the vertical axis. The input power of the phone is set at 100 mW. In this paper, IEEE/IEC 627041 averaging method is used for SAR calculation and the SAR values averaged over 10 g tissues are presented in Fig. 5 (b) and (c). The phone model without the smart sticker produces a SAR of 2.116 W/kg which is slightly higher than the maximum permissible limit. However, the application of smart sticker reduces the SAR by 30% (1.464 W/kg) which is well under the maximum safety limit.

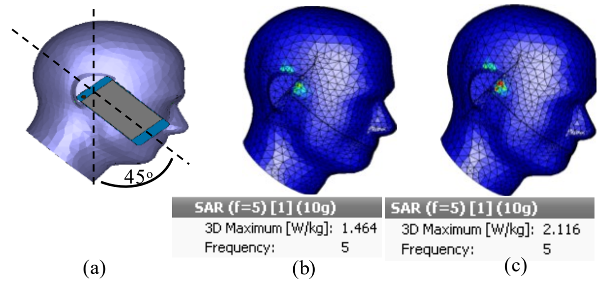

Fig. 5. (a) Position of the mobile phone with respect to the human head model and SAR distribution on the human head model; (b) without smart sticker (c) with smart sticker.

V. Conclusion

A smart sticker including Split Square Rings is presented for adapting radiation pattern in the safe direction in mobile phones. The smart sticker permits the phone antenna to steer the radiation beam away from the human head. The smart sticker operates at 5 GHz WiFi band (IEEE 802.11ac) for VOIP call and data applications. It is observed that for a reference dipole radiation, the SSR based smart sticker reduces the SAR averaged over 10 g tissues from 2.11 W/kg to a safety value of 1.46 W/kg (reduction by over 30%).

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