SAR Compliance Assessment of PMR 446 and FRS Walkie-Talkies

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The vast amount of studies on radiofrequency dosimetry deal with exposure due to mobile devices and base station antennas for cellular communication systems. This study investigates compliance of walkie-talkies to exposure guidelines established by the International Commission on Non-Ionizing Radiation Protection and the Federal Communications Committee. The generic walkie-talkie consisted of a helical antenna and a ground plane and was derived by reverse engineering of a commercial walkie-talkie. Measured and simulated values of antenna characteristics and electromagnetic near fields of the generic walkie-talkie were within 2% and 8%, respectively. We also validated normalized electromagnetic near fields of the generic walkie-talkie against a commercial device and observed a very good agreement (deviation <6%). We showed that peak localized specific absorption rate (SAR) induced in the oval flat phantom by the generic walkie-talkie is in agreement with four commercial devices if input power of the generic walkie-talkie is rescaled based on magnetic near field. Finally, we found that SAR of commercial devices is within current SAR limits for general public exposure for a worst-case duty cycle of 100%, that is, about 3 times and 6 times lower than the limit on the 1 g SAR (1.6 W/kg) and 10 g SAR (2 W/kg), respectively. But, an effective radiated power as specified by the Private Mobile Radio at 446 MHz (PMR 446) radio standard can cause localized SAR exceeding SAR limits for 1 g of tissue. Bioelectromagnetics. 36:517–526, 2015.

Key words: modeling; exposure; two-way radio transceiver; absorption assessment; helical antenna

INTRODUCTION

Although a vast amount of studies on dosimetry deal with exposure due to mobile devices and base station antennas for cellular communication systems, the mobile phone is not the only device operated in proximity of the human head. Using the case study of the walkie-talkie, we draw attention to a device that gained interest as an alternative to cellular phones for short-range communications. Walkie-talkies, or two-way radios, operate close to the human head as is the case for mobile phones. Typical operating positions of a walkie-talkie are in front of the face, whereas a mobile phone is typically operated next to the ear. When operating a walkie-talkie, its antenna could be just in front of the eye. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) restricts local-averaged specific absorption rate (SAR) in 10 g (applicable in Europe) based on cataract in the eye of a rabbit [ICNIRP, 1998]. As opposed to mobile phones, no or little attention is paid to walkie-talkies in dosimetry, although compliance tests also apply to these devices. Cecil et al. [2014] and Dimbylow et al. [2003] investigated numerically peak 10 g localized SAR induced by Terrestrial Trunked Radio (TETRA) transmitters positioned around the human body.

In recent years, walkie-talkies are more frequently encountered as a short-range communication device (e.g., adults give a walkie-talkie to their children when they go to play outside their house; parking lot attendants employ a walkie-talkie to direct the traffic inside a parking lot to assist drivers in finding a free parking spot, etc.) Advantages of walkie-talkies with respect to cellular phones are their ease-of-use (push-to-talk), their inexpensiveness, and free-of-charge communications.

In Europe, a walkie-talkie operates according to the Private Mobile Radio at 446 MHz (PMR 446) standard; in the United States, Family Radio Service (FRS) is authorized for license-free short-range voice communication [ERC, 1998; ETSI, 2001a, 2015;

Conflicts of interest: None.

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FCC, 2015]. FRS uses 14 channels within frequency bands 462.5625–462.7125 MHz and 467.5625–467.7125 MHz. PMR 446 specifies eight channels within frequency range 446.0–446.1 MHz. Each channel has a bandwidth of 25 and 12.5 kHz for FRS and PMR 446, respectively. Maximum allowed Effective Radiated Power (ERP) is 500 mW for both systems. Frequency modulation (FM) has been adopted as modulation scheme. Relative low frequency, effective radiated power of 500 mW, use of walkie-talkies by children, position in front of the face, and limited number of exposure studies for walkie-talkies attracted our attention to these devices.

The objective of this study was to develop and evaluate an accurate helical antenna of a generic walkie-talkie for compliance assessment with ICNIRP [1998] and FCC [2001] guidelines. We designed a generic walkie-talkie and evaluated it in free space and below a flat phantom against a real device. This validation between model and real device will allow us to use the walkie-talkie model in future studies (e.g., to evaluate absorption in anatomical human body models.) To our knowledge, compliance of walkie-talkies operating according to PMR 446 and FRS standards under worst-case conditions has not yet been investigated in literature. In addition, compliance of four commercial walkie-talkies was evaluated. The model is obtained by reverse engineering and is validated by reflection, near-field, and far-field measurements. The use of helical monopole antennas as a model for portable handheld devices have been mainly discussed for mobile-phone technologies [Lazzi and Gandhi, 1998; Koulouridis and Nikita, 2004] operating in frequency bands around 900 MHz and 1800 MHz. In this study, a helical monopole antenna model of a walkie-talkie operating at 446 MHz was designed to study electromagnetic fields induced in the human head by walkie-talkies. A model is preferred over a real walkie-talkie device mainly for two reasons: firstly, antenna characteristics (e.g., reflection at input terminals of a model can be measured accurately); secondly, input power is easily adjustable as one can feed using a signal generator contrary to a real device. The model also allows study of influence of dimensions and material parameters on antenna characteristics and absorption or SAR assessment in realistic human head models.

MATERIALS AND METHODS

Generic Walkie-Talkie Design

We developed a generic walkie-talkie by reverse engineering of a commercially available PMR 446 radio, that is, the COBRA MT500 (Cobra Electronics, Chicago, IL) shown in Figure 1a. We dismantled the COBRA MT500 and developed a generic walkie-talkie (Fig. 1b) based on physical dimensions of the antenna structure (including coating around antenna) and Printed Circuit Board (PCB). The model consisted of a helical antenna mounted on a rectangular ground plane. Terminals of the source connected the helical antenna and ground plane of the model. To limit complexity of the model, the PCB of the walkie-talkie was replaced by a perfectly conducting ground plane and the case was removed. The helical antenna fits in a dielectric cover. This cover around the helical antenna influences antenna characteristics of the model. Dielectric properties of this cover were unknown and we derived properties by tuning simulated antenna characteristics and near-field distributions to measured results.

SAR Assessment

We tested SAR compliance for the generic walkie-talkie as well as for four commercially available walkie-talkies (Table 1) according to IEC standard 62209-2 [IEC, 2005]. We placed the walkie-talkie at a distance (d) below an oval flat phantom as shown in Figure 2. We did not take the user's hand into account. IEC standard 62209-2 [IEC, 2005] for compliance testing does not specify hand position because dosimetric studies [Balzano et al., 1995; Kuster et al., 1997a, b; Meyer et al., 2001] suggest that excluding the hand in modelling constitutes a conservative case scenario for SAR in head.

Measurement Setup

Measurements of reflection and input impedance were performed in an anechoic room using a vector network analyzer (VNA) (type HP8710, Agilent Technologies [formerly Hewlett Packard], Palo Alto, CA). The far-field characteristics in terms of Total Radiated Power (TRP) and the Effective Radiated Power (ERP) were measured. TRP measurements were performed in a reverberation chamber according to TCO'01 Certification of Mobile Phones [TCO Development, 2008]. Measurement uncertainty was 1 dB. ERP measurement was performed in an anechoic room according to European Telecommunications Standards Institute (ETSI) standard EN 300 296-2:2001-03 [ETSI, 2001b]. Measurement uncertainty was 3.3 dB, which is within the uncertainty boundary of 6 dB specified by the ETSI standard. This large uncertainty is due to simplifications built into measurement methodology to reduce time and costs of tests. For walkie-talkies, ERP was only measured in eight different directions in the azimuth plane

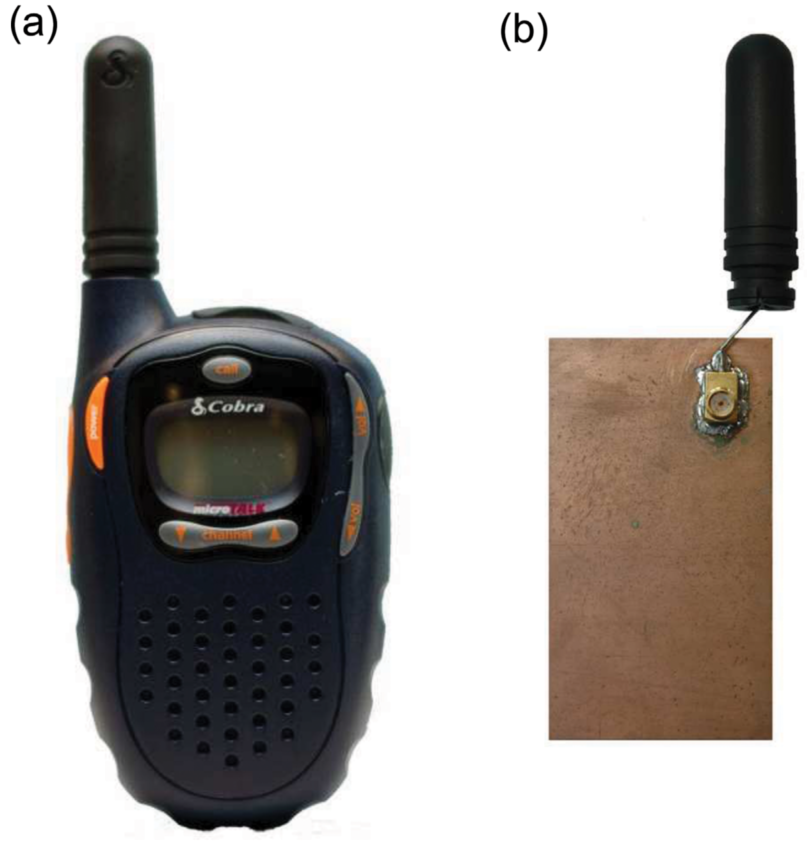

Fig. 1. (**a**) COBRA MT500 (Cobra Electronics); (**b**) back of derived model with helical antenna enclosed by a dielectric cover (bazooka balun is not shown).

resulting in an uncertainty of 3.3 dB. Near fields were measured in an indoor environment using a robot and DASY3 measurement system with the following probes: E-field probe ER3DV6 and H-field probe H3DV6 (SPEAG, Zurich, Switzerland). Reflections of the environment and robot arm were minimized by placing absorbers.

Measurement setup for SAR compliance testing consisted of a robot (Staubli Type Rx90B L, Staubli, Pfäffikon, Switzerland), a DASY4 measurement system (SPEAG), a power meter (Agilent E4419B), power sensors (8482H, Agilent), a directional coupler (HP775D Dual Directional Coupler 450-940 MC, Agilent), an RF termination (Meca 480-1, Agilent), a generator (HP8647A, Agilent), a network analyzer (HP8753E, Agilent), and the flat phantom (ELI4, SPEAG) filled with head simulating liquid (HSL450, SPEAG). The DASY4 measurement system consisted of data acquisition electronics (DAE3 from SPEAG) and a dosimetric probe (ET3DV6 from SPEAG). Figure 2 shows setup for performing dosimetric measurements. The dosimetric system (probe and data acquisition electronics) was attached to a robot. Robot and data acquisition electronics were connected to a server and managed through the graphical user interface of a laptop or desktop computer. Walkie-talkies and the generic walkie-talkie were placed at short

TABLE 1. Four Commercially Available Walkie-Talkies

Walkie-talkie (manufacturer)
COBRA MT 500 (Cobra Electronics, Chicago, IL)
TwinTalker 3300 (Topcom, Tilburg, The Netherlands)
TwinTalker 1300 (Topcom, Tilburg, The Netherlands)
Alecto FR-20 (Alecto Electronics, ’s-Hertogenbosch, The Netherlands)

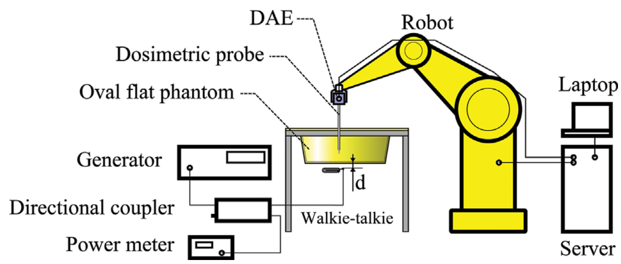

Fig. 2. Drawing of setup for dosimetric measurements.

distance (d) below oval flat phantom. Oval flat phantom was filled with head simulating liquid (HSL450 from SPEAG) as suggested by IEC 62209 [IEC, 2001]. Dielectric properties of the liquid at 450 MHz were $\sigma = 0.87$ S/m and $\varepsilon_r = 43.5$. Separations between liquid and walkie-talkie were 2 mm (touch position), 15, 30, and 50 mm. For the generic walkie-talkie we did not measure in touch position (we did not want the ground plane of the generic walkie-talkie to make contact with the shell of the phantom) and at 50 mm (due to antenna's low efficiency, we could not measure at this distance). In the case of the generic walkie-talkie, it was connected to a radiofrequency (RF) generator. Input power of antennas was measured by a power meter via a directional coupler.

The worst-case uncertainty of the DASY4 measurement system was mentioned in the manual [SPEAG, 2008] provided with the system. Combined standard uncertainty on the local-averaged SAR in 1 g and 10 g equals 10.9% and 10.7%, respectively; expanded standard uncertainty on local-averaged SAR in 1 g and 10 g equals 21.9% and 21.4%, respectively. This worst-case uncertainty budget for DASY4 was assessed according to IEEE 1528 [IEEE, 2003]. For specific tests and configurations, uncertainty can be considerably smaller [SPEAG, 2008].

The commercially available walkie-talkies were placed below the flat phantom with their push-to-talk button fixed during measurement in order to transmit continuously. Before every measurement, fully-charged batteries were placed in walkie-talkies to ensure transmission at maximum power. A walkie-talkie uses half-duplex communication resulting in a varying duty cycle from 0% to 100%. A continuously transmitting device has a duty-cycle of 100%. Hence, a worst-case duty cycle of 100% was selected for compliance testing.

Besides four commercially available walkie-talkies, we also assessed peak local-averaged SAR in 1 g and 10 g for the hand-made generic walkie-talkie. Measured peak local-averaged SAR values were compared with simulations.

Numerical Methods

We employed the finite-difference time-domain (FDTD) solver available in the three-dimensional full-wave electromagnetic software package SEMCAD-X (SPEAG) for performing numerical analysis in free space and below the oval flat phantom. In FDTD calculations, simulation domain is finite and boundary conditions are used to mimic free space. We applied uni-axial perfectly matched layers (UPML) at the boundaries. The number of layers was automatically set by the FDTD solver to obtain a selected efficiency of 99.9%. Padding (minimum distance between absorbing boundaries [UPML] and the bounding box around the walkie-talkie or combination of walkie-talkie and the flat phantom) was a quarter of a wavelength. Grid step for the helical antenna equaled 0.5 mm (133 times smaller than a tenth of the wavelength in free space at 450 MHz), and maximum grid step in the flat phantom was 2 mm (5 times smaller than a tenth of the wavelength in the tissue simulating liquid at 450 MHz). Based on these settings, we estimated uncertainty on peak local-averaged SAR from the study of Bakker et al. [2010, 2011]. Expanded uncertainty U ($k = 2$) on SAR_{10g} in the flat phantom filled with tissue-simulating liquid equaled 11.9% (there is no uncertainty on dielectric properties of tissue-simulating liquid because the values are specified by standards).

RESULTS

Free-Space Evaluation of the Generic Walkie-Talkie

Figure 3 shows dimensions of the derived generic walkie-talkie operating at 446 MHz and the coordinate system used in this study. Model dimensions and dielectric parameters are listed in Table 2. These values can be modified to specific dimensions of different types of walkie-talkies. The helical antenna fits in a dielectric cover with a relative permittivity (ε_r) of 3.9 and a conductivity (σ) of 12 mS/m.

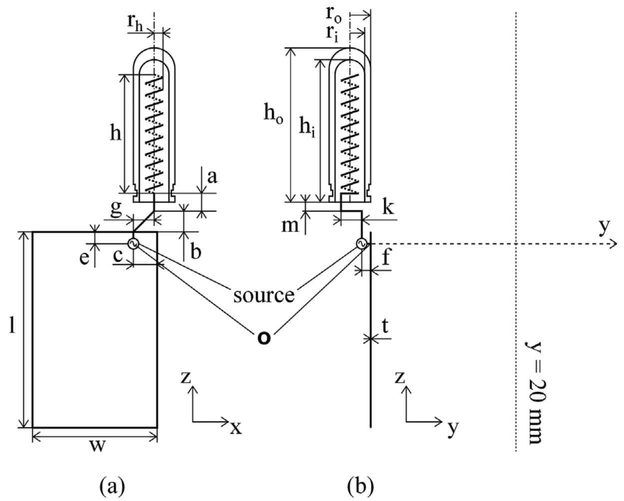

Fig. 3. Generic walkie-talkie in (**a**) xz-plane and (**b**) yz-plane. Measurement line (y-axis) and plane ($y = 20$ mm) for near fields are also shown.

TABLE 2. Dimensions of a Walkie-Talkie Model

Helical antenna		Ground plane	
a	4.2 mm	l	80 mm
b	9.8 mm	w	45 mm
c	10 mm	t	0.5 mm
e	5 mm	Antenna housing	
f	2 mm	r_i	3.5 mm
g	8.54 mm	r_o	7 mm
h	42 mm	ε_r	3.9
k	7.2 mm	σ	12 mS/m
n_{turns}	21	h_i	51 mm
r_h	2.4 mm	h_o	53 mm
r_w	0.5 mm	m	1 mm

We realized a balanced feed current at terminals of the measurement model with a bazooka or a sleeve balun [Balanis, 1982]. Operating frequency of the bazooka balun was 446 MHz. (The bazooka balun is not shown in Fig. 1b).

Return loss $|S_{11}|$ in dB of the model with respect to 50 Ω is shown in Figure 4. A very good agreement is observed between simulations and measurements. Resonance frequency f_{res} calculated by the FDTD tool is 436.5 MHz and deviates only 0.3% of the measured value f_{res}, that is, 435.2 MHz. Simulated input impedance at resonance $Z_{\mathrm{in,res}}$ equaled 20.8 Ω, measured input impedance equaled 24.5 Ω. At operating frequency of 446 MHz, input impedance of model Z_{in} was $28.6 + i30.4\ \Omega$ and $23.1 + i29\ \Omega$ for measurement and FDTD simulation, respectively.

We already mentioned that dielectric parameters of the cover (relative permittivity of 3.9, conductivity of 12 mS/m.) around the antenna were derived by tuning these parameters until simulations agreed with measurements in term of resonance frequency, return loss, and near fields.

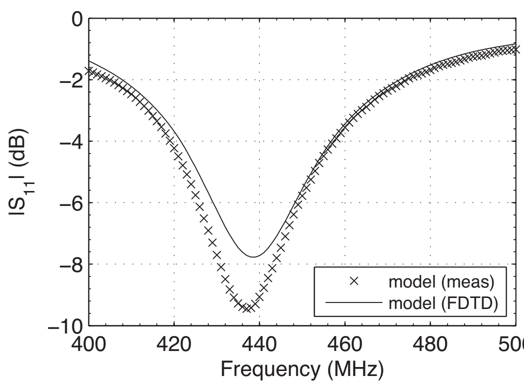

Fig. 4. Return loss $|S_{11}|$ of model.

Radiation efficiency (η) of an antenna is defined as ratio of radiated power (P_{rad}) and input antenna power (P_{in}), or $\eta = P_{\mathrm{rad}}/P_{\mathrm{in}}$ [Balanis, 1982]. Radiation efficiency was calculated using FDTD simulations. For the generic walkie-talkie, we obtained an efficiency of 53% at 446 MHz. This low efficiency was due to the reflection at input terminals of the helical antenna and ohmic losses in housing around the helical antenna introduced by the conductivity (σ) of 12 mS/m.

Far-field behavior of the generic walkie-talkie has been investigated numerically in terms of gain (G). Using FDTD, a gain of 1.07 for simulation model was obtained. This value is lower than the standard gain of a half-wave dipole antenna (G_d), mainly due to losses in the dielectric cover around the helical antenna of the model. ERP can be calculated as follows [FCC, 1997]:

$$\mathrm{ERP} = \frac{G}{G_d} P_{\mathrm{in}} \tag{1}$$

Effective radiated power was measured for the generic walkie-talkie with coating. For an input power of 10 mW, measured maximum ERP was 4.9 mW (measurement uncertainty was 3.3 dB). This agreed well with simulated ERP of 4.8 mW (relative error was 2%). Based on simulated ERP for an input power of 10 mW, we calculated that input power of the helical antenna (or output power of generator) must be set to 1042 mW to obtain maximum allowed ERP of 500 mW as specified by the PMR 446 [ERC, 1998] and FRS standard [FCC, 2015]. This input power is used below to determine compliance of the model with safety guidelines [ICNIRP, 1998; FCC, 2001].

Near fields of the model were simulated and measured in the y-plane at 20 mm from the model ($y = 20$ mm) according to the setup shown in Figure 3. This plane was parallel to the ground plane of the generic walkie-talkie (or PCB of real devices) at a distance that might be considered a typical separation distance value when a walkie-talkie is operated in front of the face. ERP was set to 500 mW. Figure 5 shows simulated ([a] and [b]) and measured ([c] and [d]) RMS electric E_{rms} ([a] and [c]) and RMS magnetic H_{rms} ([b] and [d]) near fields of the model at $y = 20$ mm. One observes that distribution of the electric and magnetic field as well as absolute field values of the simulations agree well with measurements. Dots in Figure 5 show the position of the maximum field values. The position of the maximum RMS E-field and H-field was situated near the helical antenna and terminals of the model, respectively. In the plane $y = 20$ mm, simulated $E_{\mathrm{rms,max}}$ (Fig. 5a)

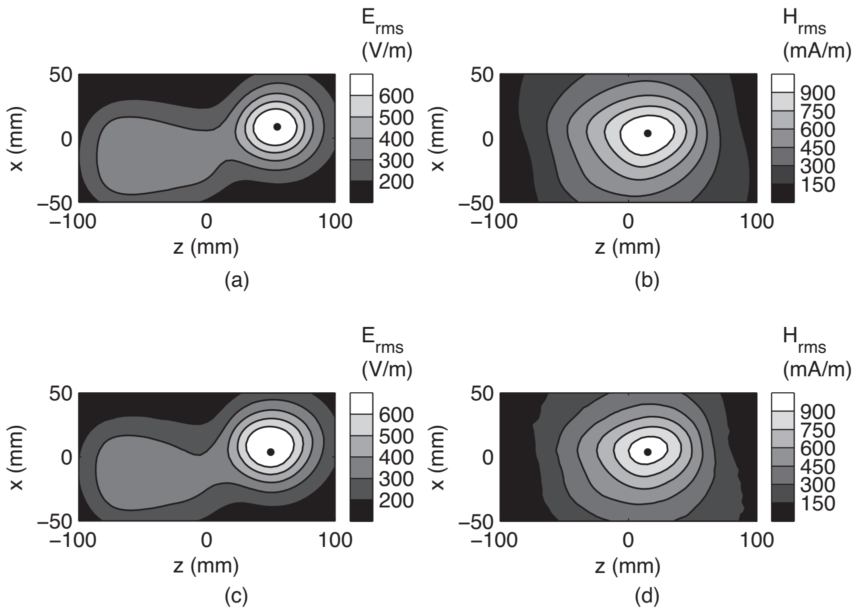

Fig. 5. (**a**) and (**b**) simulated and (**c**) and (**d**) measured electromagnetic near fields at $y =$ 20 mm of generic walkie-talkie.

equals 762 V/m in the point ($x = 10$ mm, $z = 55$ mm) and deviates only 1.6% from measured field value, that is, $E_{\mathrm{rms,max}}$ of 750 V/m in point ($x = 5$ mm, $z = 50$ mm). In the same plane $y = 20$ mm, simulated $H_{\mathrm{rms,max}}$ is 1080 mA/m in ($x = 5$ mm, $z = 15$ mm) and deviates 7.7% from measured $H_{\mathrm{rms,max}}$ of 1003 mA/m in ($x = 5$ mm, $z = 15$ mm).

Free-Space Evaluation of Four Commercially Available Walkie-Talkies

Besides the COBRA MT500, three other PMR 446 radios were acquired. In this section, the radiation characteristics of all the walkie-talkies (Table 1) and near-field behavior of the COBRA MT500 are investigated.

Radiation characteristics of real devices were measured at SP Technical Research Institute of Sweden (Borås, Sweden). Table 3 lists TRP, maximum ERP, and averaged ERP. Maximum effective radiated power varied from 51 mW to 138 mW. This is about 9.8–3.6 times below specification of allowed ERP for PMR 446 radios.

TABLE 3. Total Radiated Power and Effective Radiated Power of Four Commercial Walkie-Talkies

Walkie-talkie	TRP (mW)	Max. ERP (mW)	Avg. ERP (mW)
COBRA MT500	105	138	117
TwinTalker 3300	59	79	68
TwinTalker 1300	51	69	63
Alecto FR-20	44	51	47

Near fields of COBRA MT500 were measured and compared to the model of the walkie-talkie (which has dimensions based on dimensions of the COBRA MT500). We positioned the walkie-talkie in the same way as the model (see Fig. 3) such that the feed point coincided with the origin of the coordinate system. We normalized fields to the maximum field value in the plane $y = 20$ mm, because we were not able to determine input power for the real walkie-talkie. Figure 6 shows normalized electric and magnetic field in a plane for the real walkie-talkie (only measurements). These distributions agree well with simulated (see Fig. 5a and c) and the measured (see Fig. 5b and d) near field distributions of the generic walkie-talkie. Compared to the real walkie-talkie, maximum relative error for the measured and simulated model on the normalized electric field were only 1.2% and 5.2%, respectively. For normalized magnetic near field, maximum relative error for the measured and simulated model was 5.2% and 5.5%, respectively. These low deviations show that the model behaves electromagnetically like a real walkie-talkie and can be used for analysis of interaction with the human body.

SAR Assessment of Real Walkie-Talkies

Figure 7 shows peak local-averaged SAR in 1 g and (SAR_{1g}) and 10 g (SAR_{10g}) of the four

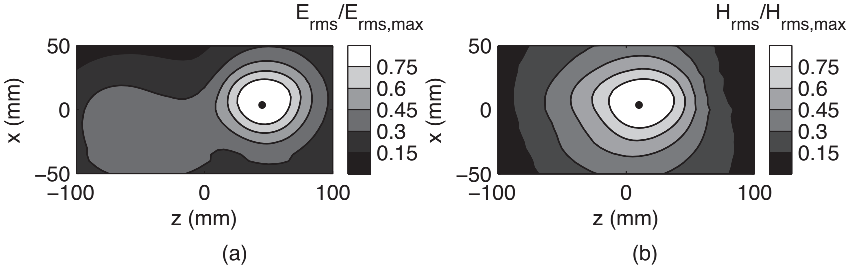

Fig. 6. Normalized RMS (**a**) electric and (**b**) magnetic near field at $y = 20$ mm of a real walkie-talkie.

commercial walkie-talkies for a duty-cycle of 100% (i.e., continuously speaking for at least 6 min.) The Alecto was not measured at a distance of 15 mm between the device and the liquid inside the flat phantom. Except for the touch position, the COBRA MT500 showed a higher SAR in 1 g and 10 g than the walkie-talkies from Topcom (Tilburg, The Netherlands) and Alecto ('s-Hertogenbosch, The Netherlands).

Highest values of the SAR_{1g} and SAR_{10g} occurred when the walkie-talkie touched the flat phantom: $SAR_{1g} = 0.52$ W/kg (Alecto) and $SAR_{10g} = 0.35$ W/kg (Alecto). These values for the touch position comply with the SAR-limits for 1 g (i.e., 1.6 W/kg) and 10 g (i.e., 2 W/kg), respectively, even for a worst-case duty cycle of 100%.

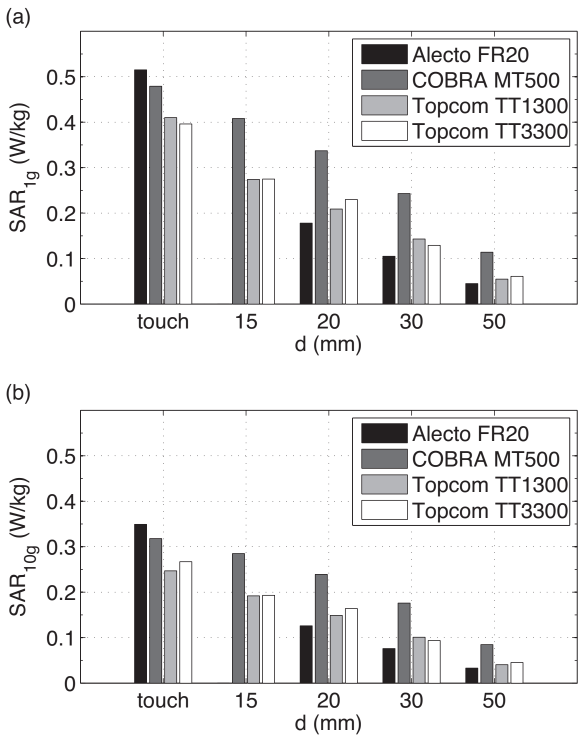

Fig. 7. Peak local-averaged SAR in (**a**) 1 g and (**b**) 10 g induced in oval flat phantom by four commercially available walkie-talkies with duty cycle of 100%.

Cecil et al. [2014] and Dimbylow et al. [2003] reported peak 10 g SAR values up to about 50% of ICNIRP limit for general public exposure for TETRA transmitters. This is higher than the maximum of 0.35 W/kg observed in our study. Besides the difference in phantom (human body model vs. flat) and distance between the walkie-talkie and the phantom, the difference was mainly due to the difference in applied power: Cecil et al. as well as Dimbylow et al. used a transmitted power of 0.25 W for the hand-held TETRA devices whereas in our study, SAR values were for typical TRP-values (in free space) of walkie-talkies ranging from 44 mW to 105 mW (Table 3).

SAR Assessment of Generic Walkie-Talkie

The input power of the generic walkie-talkie was set to 10 mW during measurement taking into account reflection losses. We validated use of the generic walkie-talkie as a substitute for real devices by comparing peak local-averaged SAR of real devices with ones of the model for the same ERP of the real devices and for the same magnetic near field. Above, we discussed ERP values of the four walkie-talkie devices. We observed that ERP of considered devices was at least 3.6 times smaller than maximum allowed ERP for PMR 446 radios. We rescaled ERP of the generic walkie-talkie (measured value of 4.9 mW and simulated ERP value of 4.8 mW for an antenna input power of 10 mW) to values listed in Table 3. The antenna input power needed to reach ERP of the walkie-talkies was applied during dosimetric measurement. Figure 8 shows the SAR_{1g} and SAR_{10g} of the generic walkie-talkie with the same ERP of the COBRA MT500. We observed that the generic walkie-talkie overestimated peak local-averaged SAR of the real devices (Fig. 7). Rescaling input

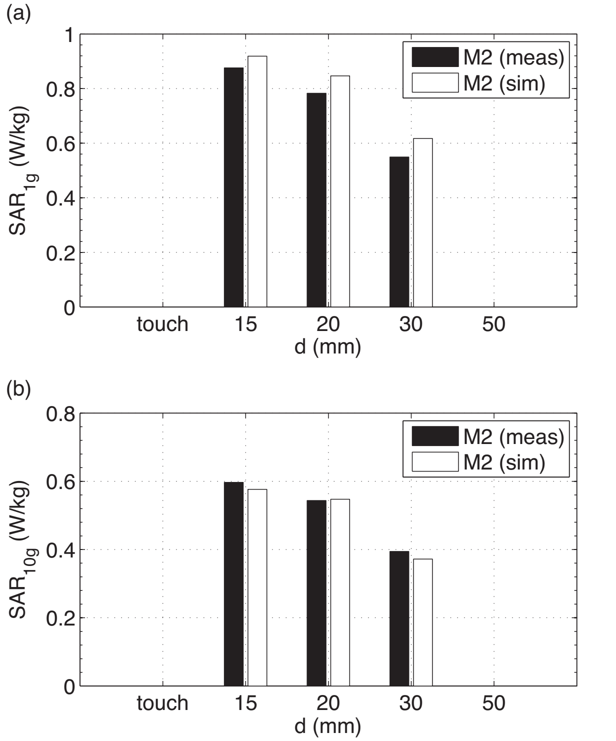

Fig. 8. Peak local-averaged SAR in (**a**) 1 g and (**b**) 10 g induced in flat phantom by generic walkie-talkie for same ERP as COBRA MT500 (100% duty cycle).

power based on ERP (a far-field characteristic) was inadequate for assessment of SAR in human tissue despite the use of the helical antenna with coating from the COBRA MT500. The ratio for SAR_{1g} and SAR_{10g} (for ERP equal to ERP of the devices) of the model and device was 2.5 and 2.3, respectively. The deviation originates from uncertainties on ERP and SAR measurements, simplifications of the model with respect to the real device and from differences in coupling when the device or model operates at close distance to the phantom. Ratio for the other real walkie-talkies was maximum 2.8 (Topcom tt3300) and 2.5 (Topcom tt3300) for SAR_{1g} and SAR_{10g}, respectively. For further numerical analysis of the SAR_{10g} in the flat phantom using the generic walkie-talkie and based on a rescaling of ERP, we will take into account a correction factor of two for SAR_{10g} value.

A better quantity for validating the generic walkie-talkie as a substitute for a real device for assessing peak local-averaged SAR is the magnetic near field. Kuster and Balzano [1992] showed that the SAR is mainly proportional to incident magnetic near field. We rescaled the maximum of the magnetic near field in a plane at a distance of 20 mm of the ground plane of the generic walkie-talkie to the maximum value of the magnetic field in the same plane above the real device. Peak-local averaged SAR of the generic walkie-talkie for a rescaling based on magnetic field is shown in Figure 9. We observed that maximum deviation on the peak local-averaged SAR was less than 26%. Thus, magnetic near field is a better quantity than far-field parameter ERP for estimating peak local-averaged SAR of a real device.

Finally, we estimated worst-case peak local-averaged SAR for the walkie-talkies. We determined peak local-averaged SAR in 1 g and 10 g for an input power that gives an ERP of 500 mW in free space (we assumed a duty cycle of 100% for worst-case evaluation) for the generic walkie-talkie and taking into account a correction factor of two (see above). Figure 10 shows that the generic walkie-talkie is not compliant to the FCC limit of 1.6 W/kg in a cube of 1 g at 15 mm. The worst-case peak local-averaged SAR in 1 g of tissue exceeded the FCC limit by up to 7% (based on simulated value). If we compared peak local-averaged SAR in 10 g of tissue with ICNIRP basic restriction of 2 W/kg, then we observed that the walkie-talkies are compliant.

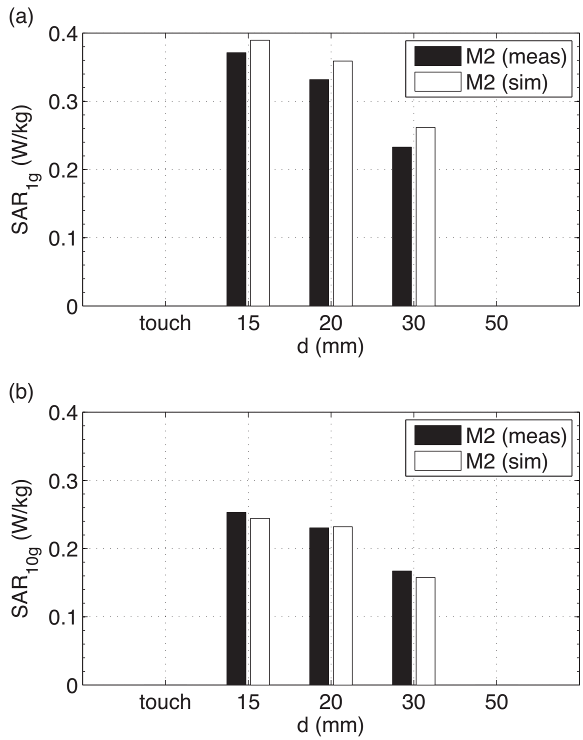

Fig. 9. Peak local-averaged SAR in (**a**) 1 g and (**b**) 10 g induced in the oval flat phantom by generic walkie-talkie for same magnetic field at 20 mm above ground plane as COBRA MT500 (100% duty cycle).

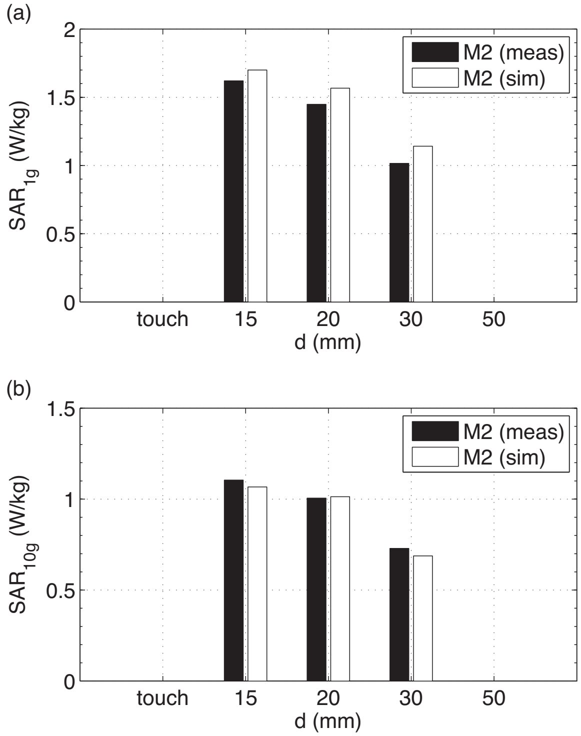

Fig. 10. Worst-case assessment of peak local-averaged SAR in (**a**) 1 g and (**b**) 10 g induced by generic walkie-talkie for ERP = 500 mW (100% duty cycle).

CONCLUSIONS

An accurate model for a walkie-talkie has been developed and very good agreement reported from simulations and measurements in terms of reflection and transmission characteristics. Near fields of the model have been validated with measured near fields of a real walkie-talkie. A relative error of less than 5.5% has been observed on the near electric and magnetic field indicating that the walkie-talkie model behaves electromagnetically as a real walkie-talkie. Therefore, the model can be used to determine electromagnetic interaction with the human body and to test compliance with safety limits. Total radiated power and effective radiated power were measured for four real or commercially available walkie-talkies and a generic walkie-talkie. Measured effective radiated power of the real walkie-talkies is about 3.6–9.8 times lower than allowed effective radiated power for PMR 446 radios.

We found that rescaling the input power of the generic walkie-talkie based on the ERP (a far-field characteristic) is inadequate for assessment of SAR in human tissue: we observed a ratio for SAR_{1g} and SAR_{10g} between the model and the device of 2.5 and 2.3. A better quantity for validating the generic walkie-talkie as a substitute for a real device for assessing peak local-averaged SAR is the magnetic near field with deviations of less than 26%.

We investigated compliance to SAR safety limits of a walkie-talkie. An effective radiated power as specified by the PMR 446 radio standard can cause a local-averaged SAR, which exceeds limits. However, based on effective radiated power of four real walkie-talkies, we showed that peak local-averaged SAR values are unlikely to exceed current SAR limits.

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