

Short communication

GSM cell phones can interfere with ionizing radiation dose monitoring equipment

¹P GILLIGAN, BSc, MSc, ²S SOMERVILLE, BSc and ¹J T ENNIS, MD, FRCR

¹Institute of Radiological Sciences/Mater Private Hospital/University College Dublin, 52 Eccles Street, Dublin 7 and ²Radiological Protection Institute of Ireland, 3 Clonskeagh Square, Dublin 14, Ireland

Abstract. Cell phone use is growing worldwide. These phones transmit to adjacent base stations using radiofrequency signals in the microwave range (~ 900 – ~ 1800 MHz). Portable electronic dose monitoring equipment is used in hospitals and other institutions to monitor and control levels of exposure to ionizing radiation, and to reassure staff. The objective of this paper is to investigate the effect of mobile phones on a sample of dose monitoring devices. Two mobile phones (Siemens C25 and Motorola CD930) were used in the study. Field strengths were measured to be in the range 0 V m^{-1} to over 100 V m^{-1} , depending on the distance from the phone, and were strongest at the beginning of a call. Personal electronic dosimeters ($n=7$), portable dose monitors ($n=4$) and contamination monitors ($n=2$) were assessed. All the units were in service. Three of the personal dosimeters showed abnormal responses when exposed to mobile phone transmission. One dosimeter (Siemens EPD-2) registered doses equivalent to a dose rate of 99 mSv h^{-1} . In addition, two of the portable dosimeters and one of the contamination monitors also gave an abnormal response. Interference was observed across a number of detector types from a number of manufacturers. Modern cell phones can interfere with ionizing radiation dose monitoring equipment. This should be taken into account when distributing these devices and when assessing results generated by them. Electromagnetic compatibility testing should form part of the commissioning and specification protocol for new dose monitoring equipment.

There has been a dramatic increase in mobile phone, or cell phone, usage in recent years. A 1998 study showed that up to 54% of the Irish population use cell phones [1]. Mobile phone use is commonplace among radiation workers who need to be in contact for emergencies, particularly among engineers, industrial radiographers, doctors and medical radiographers [2]. Electronic ionizing radiation dose monitoring is widespread in modern institutions [3]. Dose monitoring devices have provided a mechanism for monitoring low doses of radiation (in the range of microSieverts) with an instant read-out. This has provided a cost effective solution to dose monitoring and can be more pragmatic than the use of film or thermoluminescent dosimeter badges. Electronic dosimeters are based on a number of technologies. These include Geiger Muller (GM) and diode-based detectors. The majority of units contain alarms to alert the user when a pre-set dose rate is exceeded. Quantitative readings are available in most cases using a liquid crystal display (LCD). Dose and contamination monitors are widely used for a

variety of purposes. They rely on a number of detector technologies, including scintillation crystals, proportional counters, ionization chambers and GM tubes [4].

Cell phones have caused concerns regarding interference with medical devices; consequently, mobile phone use is generally restricted in hospitals [5]. Assessment of the effects of cell phones is complex, as cell phone technology has evolved rapidly in recent years [6]. GSM mobile phones emit low levels of radiofrequency energy in the microwave range (~ 900 MHz to ~ 1800 MHz). Phones now being marketed use transmitters to locate an adjacent base station and to communicate with that base station (location updating). The base station re-transmits any information received to a phone network. Speech and other information are encoded using frequency modulation and digital signal processing techniques [6–8]. The output of the phones can be measured in terms of power density (W cm^{-2}) or electric field strength (V m^{-1}). Output in this paper has been expressed in electric field strength for comparison with other papers [9, 10]. The mobile phone dynamically controls the amount of output power it needs to facilitate a call. This level will depend on the distance from

Received 21 December 1999 and in revised form 17 May 2000, accepted 9 June 2000.

and the sophistication of the base station transmitter [6]. The maximum output power of the phone will broadly depend on the class, as defined by the GSM standard. Recent hand-held phones are generally dual band, and are class IV with a maximum power output of 2 W at 900 MHz, and class I with a maximum output power of 1 W at 1800 MHz [7].

Testing protocols for electronic dosimeters have shown that these may be susceptible to electromagnetic interference in the 500 kHz to 1 GHz range [9, 10]. Indeed, some manufacturers now offer electromagnetically shielded housing for dosimeters and advertise reduced electromagnetic susceptibility levels in their dosimeters (Siemens, Germany; NDS, Texas, USA). It is the purpose of this paper to investigate the effects of modern cell phones on electronic ionizing radiation dose monitoring equipment already in service.

Methods and materials

Dose monitoring equipment that was in service and considered to be fully functioning was selected for the study. The equipment is used either in a hospital or as part of the national regulatory inspectorate and dosimetry service of the Radiological Protection Institute of Ireland. All the units had been calibrated in the previous 12 months by a certified laboratory. The devices tested in this paper are listed in Table 1. All the units were tested in a laboratory where good mobile phone reception was known to be available.

Radiofrequency field measurements were recorded using a CA 43 portable field meter (Chauvin Arnoux, France). This was calibrated in

the previous 24 months, in accordance with the French BNM-COFRAC standard (Nr2-1035), which is equivalent to the UKAS standard in the UK. Two types of GSM phones were tested in this study, the Siemens C25 (Siemens, Germany) and the Motorola CD930 (Motorola, Ireland). Both phones are GSM class IV at 900 MHz and class I at 1800 MHz.

Electric field strength was measured during connection at the start of a call and throughout a call. This was done for outgoing and incoming calls. Information was kept constant in the outgoing call by phoning a disconnected number and using a voice recording for the incoming call. A 4 s integration period of average field strength was used to facilitate monitoring of the continuous field density. The instantaneous peak (400 ms) fluctuated too rapidly to permit reasonable recording. Field strength was measured at various locations around the phone to find a maximum. Field strength was also measured at 1 m and 2 m from each phone, and the results are given in Table 2. Maximum field strength was found in the area underneath the aerial.

Each dosimeter was placed adjacent to the phone at the maximum field strength point. If an effect was observed, the unit was moved until the effect was no longer observed. The unit was then placed at 1 m from the phone. If an abnormal response was still observed, the unit was placed at 2 m from the phone, and so on. The results of the tests are shown in Table 3. Dose readings before and after were documented, as well as any activation of alarms. Alarm settings on each device were those set by the user or manufacturer and are not documented here.

Table 1. List of equipment tested and mode of operation

	Manufacturer/distributor	Detector	Display
<i>Electronic personal dosimeters</i>			
Los Alamos Rad alarm Chirper	F&J speciality products Inc. (FL, USA)	Diode	Audio & LED
EPD-2	Siemens (UK)	Diode	Audio, LED, LCD quantitative
Pocket dosimeter with LED	Appleford Instruments (UK)	GM	Audio, LED, LCD quantitative
Pocket dosimeter without LED	Appleford Instruments (UK)	GM	Audio, LCD quantitative
Stephen 6000	R.A. Stephen/Centronics (UK)	GM	Audio, LCD quantitative
Gammacom 4200	R.A. Stephen/Centronics (UK)	GM	Audio, LCD quantitative
Gothic Crellon Bleeper 3	Gothic Crellon (UK)	GM	Audio, LCD quantitative
<i>Portable dose monitors</i>			
1015 MDH	Radcal (CA, USA)	Ion chamber	LCD
Berthold LB133	Berthold (Germany)	Proportional	Analogue meter
N/E PDR1	NE Technology (UK)	GM	Analogue meter
Mini Instruments Series 1000	Mini-Instruments (UK)	GM	Analogue meter
<i>Contamination monitors</i>			
Berthold LB1210	Berthold (Germany)	Proportional	Analogue meter
Series 900	Mini-Instruments (UK)	Scintillation	Analogue meter

LED, light emitting diode; LCD, liquid crystal display; GM, Geiger Muller.

Table 2. Mobile phone electric field strength (V m^{-1}) variation with distance

Phone	Adjacent		1 m		2 m	
	Max.	During call	Max.	During call	Max.	During call
Siemens C25	125	10–25	3.1	0.1–3.1	0.5	0.2–1.1
Motorola CD930	114	10–20	1.8	0.1–0.5	0.9	0.1–0.8

Results

Maximum electric field strength was measured at the start of the call when the phone set up the call with the base station (Table 2). During the call the field strength levels were lower and fluctuated throughout the call (Table 2). The same range of levels was noted for incoming and outgoing calls. Table 3 shows that cell phones can interfere with dose monitoring equipment. In the majority of cases this interference happens only when the phone is adjacent to the dose monitoring device. The responses were the same regardless of whether the call was incoming or outgoing. In the case of one audible alarm dosimeter, the effect was observed at up to 2 m from the phone. The most marked effect was in the Siemens EPD-2 electronic personal dosimeter. This device showed dose rate levels up to 99 mSv h^{-1} at up to 60 cm from both phones tested. The displayed dose climbed more slowly ($\sim 1 \text{ } \mu\text{Sv s}^{-1}$) than that anticipated by a dose rate of 99 mSv h^{-1} . Two models of Appleford pocket dosimeter were tested. The Appleford pocket dosimeter fitted with a light emitting diode (LED) showed a rapid initial increase in dose ($335 \text{ } \mu\text{Sv}$) but no effect thereafter. This effect was difficult to reproduce consistently and required changing the

environment a number of times before it was observed. The same effect was not seen in the Appleford device without the LED.

The type of detector did not determine which dose monitoring devices were susceptible to abnormal response. A Radcal MDH 6 cc ionization chamber registered a dose of 5 mR upon exposure to the electric field strengths from each phone. The Berthold LB133 portable dosimeter showed an abnormal response that depended on field strength. A reduced effect was noted at a distance of 1 m compared with that adjacent to the phone. The Berthold contamination monitor (LB1210) registered high count rates when the phones were operated adjacent to the meter. None of the devices were affected at distances of 3 m. All the units were fully functional after exposure to a mobile phone.

Discussion

The American National Standards Institute (ANSI) [11] N42.20 and other standards give performance criteria for testing dosimeters. Included in such criteria is testing for radio-frequency/microwave interference in the range 500–1000 MHz. The Siemens EPD-2 showed

Table 3. Description of observed effects on in-service dose monitoring equipment from mobile phones

	Effect	Phones ^a	Distance
<i>Electronic personal dosimeters</i>			
Los Alamos "Chirper"	Continuous alarm	CD930, C25	<2 m
Siemens EPD	Increased dose reading ($73 \text{ } \mu\text{Sv}$ in 60 s); increased dose rate ($>99 \text{ mSv h}^{-1}$ in 5 s); alarm	CD930, C25	<60 cm
Appleford with LED	Increased dose ($335 \text{ } \mu\text{Sv}$ in 5 s)	CD930, C25	Adjacent
<i>Portable radiation monitoring equipment</i>			
1015 MDH	Increased dose reading (5 mR in 5 s)	CD930, C25	Adjacent
Berthold LB133	Increased dose rate ($50 \text{ } \mu\text{Sv h}^{-1}$ in 5 s); alarm	CD930, C25	Adjacent
N/E PDR1	Increased dose rate ($50 \text{ } \mu\text{Sv h}^{-1}$ in 5 s)	CD930, C25	Adjacent
N/E PDR1	Increased dose rate ($0.2 \text{ } \mu\text{Sv h}^{-1}$ in 5 s)	CD930, C25	1 m
<i>Contamination monitoring equipment</i>			
Berthold LB1210	Increased reading to 300–400 counts s^{-1}	CD930, C25	Adjacent

EPD, electronic personal dosimeter; LED, light emitting diode.

^a CD930, Motorola, Ireland; C25, Siemens, Germany.

interference at field strengths of 100 V m^{-1} and 20 V m^{-1} , but not 1 V m^{-1} [9, 10]. The results presented in this paper would corroborate the findings of these studies. If mobile phone interference had not been seen in any of the devices used in this study, it would not necessarily imply that mobile phones do not interfere with the device in all types of environments.

Mobile phones are generally worn in the abdominal area, attached to a belt or stored in a bag or pocket. Electronic personal dosimeters are generally worn in the area of the trunk and are usually attached to a belt clip. It is possible that they could be worn next to an active mobile phone that could generate high field strengths when setting up an incoming call. The dose and contamination monitors tested above are generally hand-held about 30–50 cm from the body. In normal use, these are less likely to register significant readings from the high electric field strengths adjacent to a belt-worn mobile phone. The effects that occurred exclusively at high field strength could be mitigated by issuing instructions with the dose measuring device that it should not be used adjacent to a mobile phone that is switched on. This instruction may become more important as belt-worn “hands free” voice-controlled phones and phones that record information in silent mode without alerting the user become more common. Two electronic personal dosimeters showed an abnormal response up to 60 cm and up to 200 cm, respectively, from both mobile phones. These dosimeters could be affected by mobile phone users other than the wearer or if the wearer is using the phone adjacent to the ear. Indeed, abnormal responses from these devices to mobile phone use in other rooms have initiated surveys for ionizing radiation sources in the authors’ hospital. Electronic personal dosimeters are often used in short surveys to reassure non-radiation workers in a hospital that they have been designated correctly. Examples of these workers would include pregnant nursing staff in intensive care units concerned about radiation doses from portable X-rays who cannot be reassured by didactic methods. The potential for cell phone interference should be considered when designing such surveys.

Assessment for mobile phone interference of dose monitoring equipment already in service and new dose monitoring equipment may provide useful information. In this paper, a simple approach has been used to test dose monitoring devices. This is similar to the technique used by the Medical Devices Agency in the UK for testing electromagnetic immunity of medical devices from mobile phones [12] and may provide the basis for a pragmatic immunity testing protocol. More extensive testing may require specialized

equipment [12, 13]. Compliance with ANSI standards [11] and other test results should be specified in tender documents for new equipment. Such information may also be available for equipment already in service. The potential to improve the susceptibility of problematic devices by replacing shielding or other techniques should be investigated.

Conclusions

Modern cell phones can interfere with ionizing radiation dose monitoring equipment. This should be taken into account when distributing these devices and when assessing results generated by them. Interference is observed over a range of detector types and manufacturers. The potential for electromagnetic interference should be assessed when commissioning and specifying these devices.

Acknowledgments

Thanks to Mr Gavan O’Duffy of Eircell Ireland, Ms Katherine Buckley of Ericsson Ireland and Mr Patrick Gilligan Senior for their assistance in this work.

References

1. Information Society Commission. Ireland’s progress as an information society. Dublin, Ireland: Government Publications Office, 1999.
2. Chapman S, Schofield WN. Lifesavers and samaritans: emergency use of cellular (mobile) phones in Australia. *Accid Anal Prev* 1998;30:815–9.
3. Goksu HY, Regulla D, Drexler G, editors. Present status of practical aspects of individual dosimetry, Part1: EU Member states, Radiation Protection 78. Brussels: European Commission, 1994.
4. Cember H. Health physics instrumentation. In: Wonsiewicz MJ, Navrozov M, editors. Introduction to health physics. London: McGraw-Hill, 1996:342–418.
5. ECRI. Cell phones and walkie-talkies. Is it time to relax your restrictive policies? *Health Devices* 1999; 28:409–13.
6. Schiller JH. Mobile communications. London: Addison-Wesley, 1999.
7. Mouly M, Pautet MB. The GSM system for mobile communications. Palasieu, France: published by the authors, 1992.
8. Meurling J, Jeans R. GSM: global systems for mobile telecommunications in “The Mobile Phone Book”. London: CMP International Publishing, 1994:101–11.
9. Hirning CR, Yuen PS. Type testing of the Siemens Plessey electronic personal dosimeter. *Health Phys* 1995;69:46–66.
10. Oak Ridge National Laboratory. Oak Ridge National Instrument Evaluation Summary: Siemens Model EPD-2 Electronic Dosimeter. Tennessee, USA: Oak Ridge National Laboratory, 1998.

11. American National Standards Institute. ANSI N42.20 "Performance criteria for active personnel radiation monitors". New York: American National Standards Institute, 1989.
12. Medical Devices Agency. Device Bulletin DB9702 "Electromagnetic compatibility of medical devices with mobile communications". London: MDA, 1997.
13. Robinson MP, Flintoft ID, Marvin AC. Interference of medical equipment from mobile phones. *J Med Eng Technol* 1997;21:141–6.