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HIGH FREQUENCY ELECTROMAGNETIC FIELDS AROUND LINEAR ACCELERATORS AND MRI

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Abstract. It is known that the linear accelerators and MRI emit electromagnetic radiation in a broad frequency range. There are very few investigations concerning these sources because of the fact that the attention has always been directed to the main risks connected to these medical devices. Up to now we have data from single measurements of such equipment. We have found out that the radiofrequency radiation is a serious problem on the working places of the medical personnel engaged in such units that often is neglected in the practice.

Keywords: non-ionising radiation, linear accelerators, magnetic resonance image, electric field strength, magnetic flux density.

AIMS AND BACKGROUND

The aim of this study is checking and hygienic assessment of non-ionising radiation at the workplace for medical systems LA and MRI.

It is known that ionising radiation, major hazardous work place factor, is emitted around linear accelerators (LA) at the workplace. As this factor is highly aggressive towards staff health, yet before the installation of such apparatuses the facility is subject to special screening that reduces the effect of ionising radiation to safe limits out of the procedure premise.

Unfortunately there is a scarce information on other hazardous factors associated with the exploitation of LA. There are single publications treating non-ionising radiation around LA (Ref. 1). Often the additional hazardous work place factors include unfavourable microclimate, noise, laser radiation, electromagnetic radiation (EMR) – non-ionising, from different frequency ranges.

Magnetic resonance image (MRI) systems to a great degree duplicate and in other cases provide different information about the patient's studied area than that obtained by computer tomography (CT). MRI is more often recommended to the patients rather than CT aiming at reducing the hazardous effects of X-ray radiation. It should not be forgotten, though, that MRI also emits hazardous physical factors at the workplace, although it does not emit ionising radiation.

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Mainly those are EMR of different range – constant magnetic field, low and radio frequency EMR – all of them non-ionising.

The objects studied are:

1. Linear accelerator Siemens – Primus HE
2. Magnetic Resonance Image –Picker Outlook 0.23T.

The major EMR sources (non-ionising) of these systems are:

LINEAR ACCELERATOR

1. Electron gun
2. Klistrone – UHF range ($f \approx 3$ GHz)
3. Supply blocks – emitting electric and magnetic fields in the ULF range mainly with frequency $f = 50$ Hz and harmonics.
4. Modulators – different frequencies depending on the frequency and modulation type
5. VDUs of personal computers
6. Patient mass – electromagnetic gears, low frequency (LF) electric and magnetic fields.

MRI

1. HF coils – EMF with $f = 9.8$ MHz
2. Power supply – $f = 50$ Hz
3. VDUs of personal computers.

EXPERIMENTAL

MEASURING METHODS AND DEVICES

In our study we performed measurements in the following frequency ranges:

- $f = 0$ Hz (constant magnetic field);
- $f = 10$ Hz ÷ 300 kHz;
- $f = 50$ Hz;
- $f = 60$ kHz ÷ 350 MHz.

MEASURING EQUIPMENT

1. Measurement device for electric and magnetic field NFM-1 (Germany) with the following technical parameters:

- frequency range (radiofrequency – RF) – 60 kHz – 350 MHz;
- dynamic range – 2 ÷ 1500 V/m;
- smallest measured value – 2 V/m;
- uncertainty ± 20 %.

2. Measuring device for electric and magnetic field type HI-3604 ('HOLADAY INDUSTRIES', USA):

– frequency range (extremely low frequencies – ELF) for electric field – f = 20 ÷ 2000 Hz;

– frequency range for magnetic field – f = 20 ÷ 1000 Hz;

– uncertainty ± 20%.

3. Measuring device for electric and magnetic field type HI-3603 ('HOLADAY INDUSTRIES', USA):

– frequency range for electric field (low frequencies – LF) – f = 2 ÷ 300 kHz;

– frequency range for magnetic field – f = 8 ÷ 300 kHz;

– uncertainty ± 20%.

4. Device for measuring constant magnetic field (CMF) of Institut Dr. Foerster Reutlingen (BRD), Magnetoscop type 1.068.01 – 1104; Lfd. No 556 (autonomous power supply 12 V):

– dynamic range from 1×10^{-3} to 1×10^{3} μT with additional probes multiplying the measuring values up to 20x;

– uncertainty < 5 %.

5. Measuring device for CMF (Omega, Czechoslovakia), Teslameter (autonomous power supply 4.5 V), No 571812:

– smallest measured value – 0.005 T

– greatest measured value – 2.0 T

– uncertainty – 5%.

Frequency non-selective method that corresponds to the frequency range of the measurement for the particular measurement devices was used at measurements.

For the LA system the measurements were made at the places of constant stay of the medical staff: by the video monitor, out of the cabins. Measurements were made also in the screened space at safety conditions for the measuring operator (X-ray radiation not active) – in 'Wait' system mode.

For the MRI system the measurements were made outside the cabin – at constant work places and inside it around the magnet inductor at different distances from the patient – at places of incidental stay of the staff.

RESULTS AND DISCUSSION

The results are presented in tables as follows:

Table 1 presents data from measurements of magnetic induction at workplaces for the MRI system.

The values of the intensity of the electric field – E, V/m, for RF range – about 9.8 MHz, measured with NFM-1 in MRI screened premise are presented in Table 2.

Table 1. Data from measurements of magnetic induction at workplaces for MRI system

No	Measurement place	Devices used	
		Dr. Försters B (μT)	Teslameter B (mT)
1	Workplace of MRI operator – at 10 cm behind glass shield	1.0	<0.002
2			<0.002
3	In front of a door of a screened MRI premise	5.0	< 0.002
	In a screened premise		
4	Direction operator – MRI (workplace – MRI operator)		
4.1	at 1 m from MRI	–	100
4.2	at 2 m from MRI	–	7.0
4.3	at 3 m from MRI	–	0.3
5	Direction MRI – right wall (vs. the operator)	–	
5.1	at 1 m from MRI	–	110
5.2	at 2 m from MRI	–	5.0
5.3	at 3 m from MRI	–	0.1
6	Direction MRI – left wall (vs. the operator)		
6.1	at 1 m from MRI	–	112
6.2	at 2 m from MRI	–	7.0
6.3	at 3 m from MRI	–	0.15
7	Direction MRI – operator		
7.1	at 3.0 m from MRI		0.20

Table 2. Values of the intensity of the electric field – E, V/m, for RF range – about 9.8 MHz, measured with NFM-1 in MRI screened premise

MRT regime by number of cuts	Bby hands E (V/m)	By body E (V/m)	Permissible stay duration* (h)
49	28	3.5	4.08
18	20	8.0	8.0
96	7.0	1.0	>8
11	25	3.0	5.12
14	25	12	5.12
18	30	14	3.55

*The maximum stay duration is calculated for the values measured in the screened premise and by the operator's hands, on the basis of the standard BNS 145250-90.

The results from measurements for the LA system of electric and magnetic fields in ELF and LF ranges measured with the low frequency measurement system HI 3604/3603, are presented in Table 3.

Table 3. Results from measurinements for LA system of electric and magnetic fields in ULF and LF range measured with the low frequency measurement system HI 3604/3603

No	Measurement place	HI 3604		HI 3603	
		E (V/m)	B (mG)	E (V/m)	B (mG)
I	Premise 'Dosimetric planning'				
1	Workplace with two monitors				
1.1	Monitor COMPAQ P1210 – to the right				
	at 10 cm	1.50	31.90	0.20	0.24
	at 50 cm	1.47	0.67	0.20	0.10
1.2	Monitor COMPAQ P1210 – to the left				
	at 10 cm	1.55	20.00	0.20	0.12
	at 50 cm	1.50	0.89	0.20	0.08
	Workplace with two monitors	1.45	0.69	0.20	0.08
2	Monitor SONY Trinitron Multiscan E210				
	at 10 cm	18.00	17.00	7.09	1.72
	at 20 cm – workplace	1.46	0.49	6.45	0.36
	at 50 cm			0.20	0.14
3	VT 510				
	at 10 cm	5.00	20.00	38.20	8.74
	at 50 cm	1.65	0.31	0.52	0.16
4	SONY Beam Shepard				
	at 10 cm	3.32	14.90	38.90	11.25
	at 30 cm	1.46	0.53	0.82	0.26
	at 50 cm	1.45	0.45	0.37	0.13
II	Premise – operator of LA				
5	Workplace with two monitors				
5.1	Monitor SONY Trinitron Multiscan E210 – to the right				
	at 10 cm	2.71	28.30	71.0	3.23
	at 30 cm				0.50
	at 50 cm	3.76	0.97	0.36	0.16
5.2	Monitor SONY Trinitron Multiscan E210 – to the left				
	at 10 cm	36.9	14.98	68.90	2.28
	at 30 cm				0.28
	at 50 cm	7.08	0.68	0.28	0.17
5.3	Monitor SONY for watching the patient				
	at 20 cm in front of monitor	53.90	3.06	0.89	0.48
III	Internal premise for LA				
1	by electric switchboard, at 20 cm	1.46	44.40		
2	by supply wires, at 10 cm	1.46	59.80		
3	by control panel of LA at 20 cm	1.47	8.89		

The measured values of different non-ionising radiation (NIR) are discussed referring to acting national regulations. Below are presented the maximum ad-

missible values for the relevant frequency ranges according to the above regulations.

The intensities of the electric field and magnetic induction at 50 cm from VDU screens are within the maximal limits of BSS 14525-90 (Ref. 2) and Ordinance No 7 (Ref. 3) for both installations. They also correspond to the requirements for EMR according to technical norms MPR II for electromagnetic emission. This suggests that no measures are necessary for protection of medical staff working with VDUs others than those related to the visual task.

The intensities of the high frequency (HF) electric field at MRI out of the protective cabin are within the maximum admissible values. The stay of the staff inside the cabin should be restricted if it is necessary to stay close to the emitting system. The restrictions are listed in Table 2 and, as seen, they are fully executable as the necessary stay duration is shorter than the restriction set.

The values of the constant magnetic field measured in the screened MRI premise are within the maximal admissible limits (60 mT) for constant irradiation during a working shift and at some places – within the limits for short-time exposure (2T), and Ordinance No7 does not set admissible stay durations at values above 60 mT.

Table 4. Permissible levels for electric and magnetic fields in Bulgaria

Standard	Frequency range	Electric field (E)	Magnetic field (B/H)
Ordinance No 7	1-100 Hz	25 kV/m	60/f mT*
	0.1-4 kHz	2.5×10^6/f V/m	60/f mT
	4-60 kHz	625 V/m	60/f mT
Bulgarian State Standard 14525	0.06-3 MHz	500	800 A/m

* f is the frequency of the EMR (Hz); ** the limit values are the maximum admissible according to the standard. Under those intensities is determined the maximum stay duration (the norms incorporate exposure – real time of human stay in EMF conditions).

CONCLUSIONS

The two single pilot studies of some NIR of the two medical systems – linear accelerator and scanner with nuclear-magnetic resonance do not show exceeding of hygienic limits outside the protective cabins (procedure premises).

The stay inside of LA cabins is not permitted while temporary stay around MRI is safe under the following required conditions:

- restricted stay duration according Table 2;
- restricted stay duration near the magnet at distances where the magnetic induction exceeds the value B = 60 mT during more than half of the working time;

• restricted employment of individuals with active implants.

This study does not enable a firm conclusion concerning the risk from exposure to other accompanying work place factors for similar medical systems. The results refer only to the studied systems and measured frequency ranges. The ultimate standpoint requires performing similar planned measurements around different LA and MRI systems with assessment of the real exposure time.

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