

## The New EU Proposal vs. 2004/40/EC - An MR Exposure Data Comparison

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**Introduction:** In the near future the European Union directive 2004/40/EC [2] regulating the exposure of workers to electro-magnetic fields will be replaced by a new proposal [3]. This proposal will replace the current restrictive limits of  $dB/dt = 200 \text{ mT/s} @ 1 \text{ Hz}$  for movements in magnetic fields by a range of values between  $5.17 \text{ T/s}$ - $0.67 \text{ T/s}$  at  $0.1 \text{ Hz}$ - $1 \text{ Hz}$ . On the other hand, an ICNIRP draft proposal allows values from  $18 \text{ T/s}$ - $1.8 \text{ T/s}$  at  $0.1 \text{ Hz}$ - $1 \text{ Hz}$  for both translations and rotations [4]. In this work the proposed limit values are compared to measured MR exposure data.

**Materials and Methods** Exposure data from 37 volunteers at MR systems up to 7 Tesla were acquired. The volunteers were asked to wear a calibrated magnetic field probe [5] at their forehead during work at 3 different MR systems (Magnetom Avanto 1.5T, TIM Trio 3T, 7T, all Siemens, Erlangen, Germany). Three exposure parameters were recorded simultaneously: the magnetic flux density  $B_0$ , the time derivative flux density  $dB/dt$  and the time-varying magnetic flux  $d\Phi/dt$ . For comparison with the ICNIRP proposal an additional  $dB/dt_{\text{rot+trans}}$  including both rotation and translation was calculated according  $dB/dt_{\text{rot+trans}} = V_{\text{ind}} / A$  where  $A$  depicts the coil area. The exposure data was compared to the limits of 2004/40/EC, the EU proposal COM(2011)348, and the ICNIRP draft at 1 Hz.

**Results**  $d\Phi/dt$  values calculated from the measurement data and the coil diameter of 5 cm amounted to  $0.53/1.76/4.75 \text{ mWb/s}$  for the EU [2]/Proposal [3]/ ICNIRP [4] limit. Table 1 summarizes the measurements of all 37 volunteers, black: 1.5T, red: 3T, blue 7T. Data during a routine procedure at the 7T system is shown in figure 1.

**The current EU limits [2]** were exceeded in 33 measurements. Maximum peak value ( $dB/dt_{\text{trans}} = 3,3 \text{ T/s}$ ) was detected at the 7T MR system (cf. tab.1 #16), and average of  $dB/dt_{\text{trans}}$  also exceeds the limit. If translation and rotation is considered, the  $d\Phi/dt$  or ICNIRP  $dB/dt_{\text{rot+trans}}$  exceeds the current limit in 35 data sets and the average exceeds the limit in 18 measurements. The maximum  $dB/dt_{\text{rot+trans}}$  of  $7.75 \text{ T/s}$  was measured at the 7T system.

**The new proposal limit values [3]** for peak  $dB/dt_{\text{trans}}$  are exceeded only in 13

procedures, and average values always stay below the limit. For  $dB/dt_{\text{rot+trans}}$  the limit is exceeded in 32 (peak) and 2 (average) measurements. For the lower end of the frequency range ( $0.1 \text{ Hz}$ ) 12 datasets (peak) exceed the limit.

**The suggested ICNIRP draft limit values [4]** are exceeded in 2 measurements (peak  $dB/dt_{\text{trans}}$ ). For both translation and rotation  $dB/dt_{\text{rot+trans}}$  exceeds the limit in 28 (peak) datasets. For the lower end of the frequency range ( $0.1 \text{ Hz}$ ) no dataset exceeds the limit. The average values always stay below the limit for both  $dB/dt_{\text{trans}}$  and  $dB/dt_{\text{rot+trans}}$  approaches.

**Discussion** Both new proposals of the EU and ICNIRP provide higher exposure limits for the work in the magnetic field but as shown can be exceeded. Since transient effects like vertigo, nausea or magnetophosphenes are caused at high  $dB/dt$  values the new limits can help in reducing these effects. Therefore an acoustic / optic response system is planned for volunteer feedback.

**References** [1] Directive 2012/11/EU, [2] Directive 2004/40/EC, [3] COM (2011) 348, [4] ICNIRP Draft Feb/2012, [5] Groebner et al. Magn Reson Mater Phy (2011) 24:315-322

Table 1: MR exposure measurements (peak/avg); 1.5T:#1-6; 3T:#7-13; 7T:#14-37

#	$dB/dt_{\text{trans}}$ [T/s]		$d\Phi/dt$ [mWb/s]		$dB/dt_{\text{rot+trans}}$ [T/s]	
	1	0.63	0.05	16.39	0.47	6.20
2	0.32	0.04	7.04	0.67	2.66	0.25
3	0.53	0.01	10.63	0.16	4.02	0.06
4	0.48	0.02	8.20	0.12	3.10	0.05
5	0.06	0.01	0.24	0.02	0.09	0.01
6	0.12	0.02	1.05	0.07	0.40	0.03
7	0.43	0.04	10.28	0.23	3.89	0.09
8	0.51	0.05	4.99	0.61	1.89	0.23
9	0.25	0.04	5.29	0.25	2.00	0.09
10	0.15	0.01	2.23	0.32	0.84	0.12
11	0.03	0.00	0.25	0.03	0.10	0.01
12	0.29	0.08	0.67	0.23	0.25	0.09
13	0.28	0.03	0.90	0.08	0.34	0.03
14	0.88	0.18	17.97	3.61	6.79	1.37
15	0.51	0.07	20.51	1.22	7.75	0.46
16	3.38	0.21	19.80	2.75	7.48	1.04
17	0.51	0.07	20.51	1.22	7.75	0.46
18	0.81	0.08	12.17	0.51	4.60	0.19
19	0.47	0.10	9.89	0.59	3.74	0.22
20	0.87	0.18	13.91	1.18	5.26	0.45
21	0.31	0.04	14.32	0.34	5.41	0.13
22	0.47	0.15	15.24	1.03	5.76	0.39
23	0.25	0.01	3.10	0.06	1.17	0.02
24	0.20	0.03	2.40	0.13	0.91	0.05
25	0.63	0.12	9.80	0.53	3.71	0.20
26	0.42	0.10	2.57	0.41	0.97	0.15
27	0.35	0.03	6.91	0.18	2.61	0.07
28	0.44	0.08	6.15	0.53	2.32	0.20
29	0.74	0.11	12.55	0.71	4.74	0.27
30	0.81	0.08	12.64	0.43	4.78	0.16
31	1.93	0.20	16.27	1.05	6.15	0.40
32	1.20	0.19	19.78	0.96	7.48	0.36
33	1.28	0.16	12.03	0.80	4.55	0.30
34	1.28	0.16	12.05	0.82	4.56	0.31
35	1.48	0.15	19.79	0.79	7.48	0.30
36	1.49	0.14	17.43	0.68	6.59	0.26
37	1.20	0.12	12.57	0.61	4.75	0.23

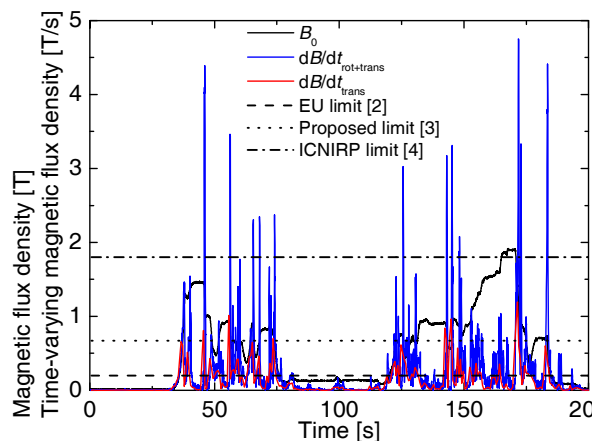


Figure 1: 7T measurement. The black/blue/red line depicts  $B_0 / dB/dt_{\text{rot+trans}} / dB/dt_{\text{trans}}$ . The horizontal lines represent the limits. Dashed: current EU limit. Dotted: EU proposal limit. Dash-dotted: ICNIRP draft limit.