ExpoM - ELF Utility: Reference Levels for magnetic flux density and computation of Exposure Index (EI) value

1 Introduction

Starting from version 1.1.0 and newer, ExpoM-ELF Utility offers the possibility to evaluate the measurements relative to a selection of regulatory masks. The evaluation is performed in the frequency domain. This application note gives an overview of the implemented masks and the method used for the calculation of the exposure index (EI) value.

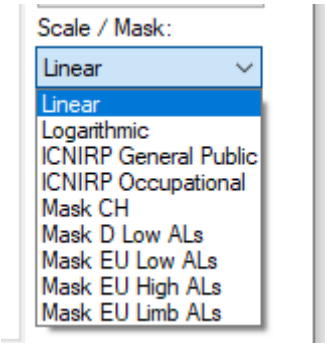

Figure 1: Reference level masks implemented in ExpoM-ELF Utility v1.1.0

2 Reference Levels

The reference levels define the magnetic flux density which shall not be exceeded in order to ensure a safe working or living environment and avoid unpleasant or dangerous sensory effects under all circumstances. As most such effects are ultimately caused by induced electric fields in the tissue (and thus the time derivative of the magnetic field), the reference levels for magnetic flux density generally decrease with increasing frequency. The exact values however do significantly vary depending on country, specified environment and included safety margins. This chapter gives an overview of the masks implemented in ExpoM-ELF Utility.

2.1 ICNIRP

The ICNIRP Reference Levels [1] are adopted at least partially by many countries. ICNIRP suggests different masks for general public and occupational exposure.

Frequency range	Magnetic flux density General Public [µT] (RMS)	Magnetic flux density Occupational [µT] (RMS)
1 - 8 Hz	$4.0 \times 10^4/f^2$	$2.0 \times 10^5/f^2$
8 - 25 Hz	$5.0 \times 10^3/f$	$2.5 \times 10^4/f$
25 - 400 Hz	200	$3.0 \times 10^5/f$
300 - 400 Hz	200	1000
400 Hz - 3 kHz	$8.0 \times 10^4/f$	$3.0 \times 10^5/f$
3 kHz - 100 kHz	27	100

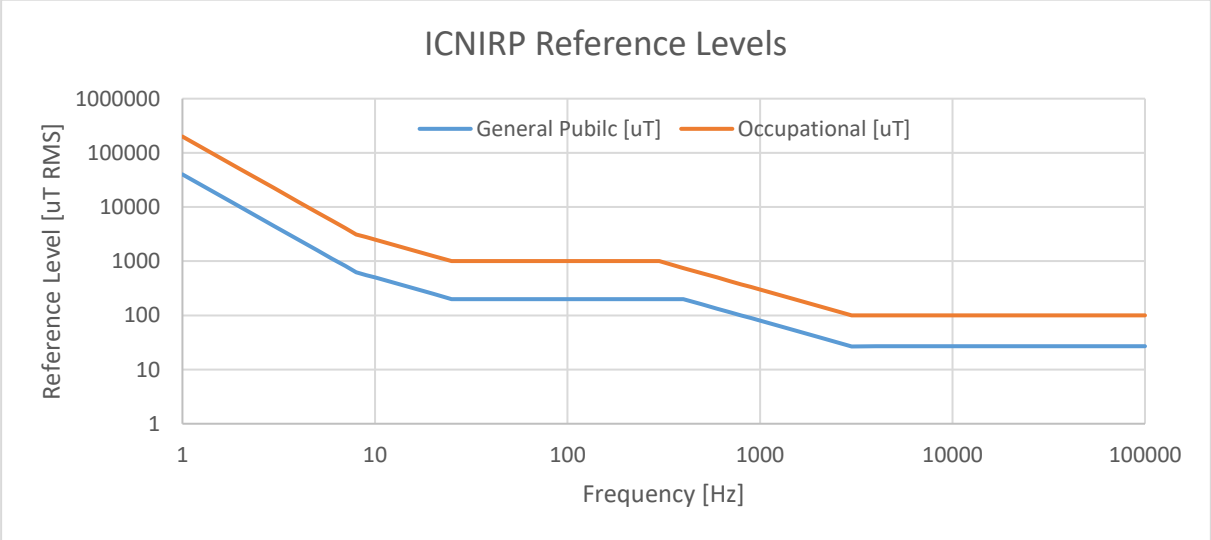

Figure 2: ICNIRP Reference levels for magnetic fields in the range from 1 Hz to 100 kHz [1].

2.2 European Union

The EU defines a set of so-called action levels (ALs) levels in the directive 2013/35/EU [2].

Frequency range	Magnetic flux density Low ALs(B) [µT] (RMS)	Magnetic flux density High ALs(B) [µT] (RMS)	Magnetic flux density ALs for exposure of limbs to a localised magnetic field [µT] (RMS)
1 - 8 Hz	$2.0 \times 10^5/f^2$	$3.0 \times 10^5/f$	$9.0 \times 10^5/f$
8 - 25 Hz	$2.5 \times 10^4/f$	$3.0 \times 10^5/f$	$9.0 \times 10^5/f$
25 - 300 Hz	1000	$3.0 \times 10^5/f$	$9.0 \times 10^5/f$
300 Hz - 3 kHz	$3.0 \times 10^5/f$	$3.0 \times 10^5/f$	$9.0 \times 10^5/f$
3 kHz - 100 kHz	100	100	300

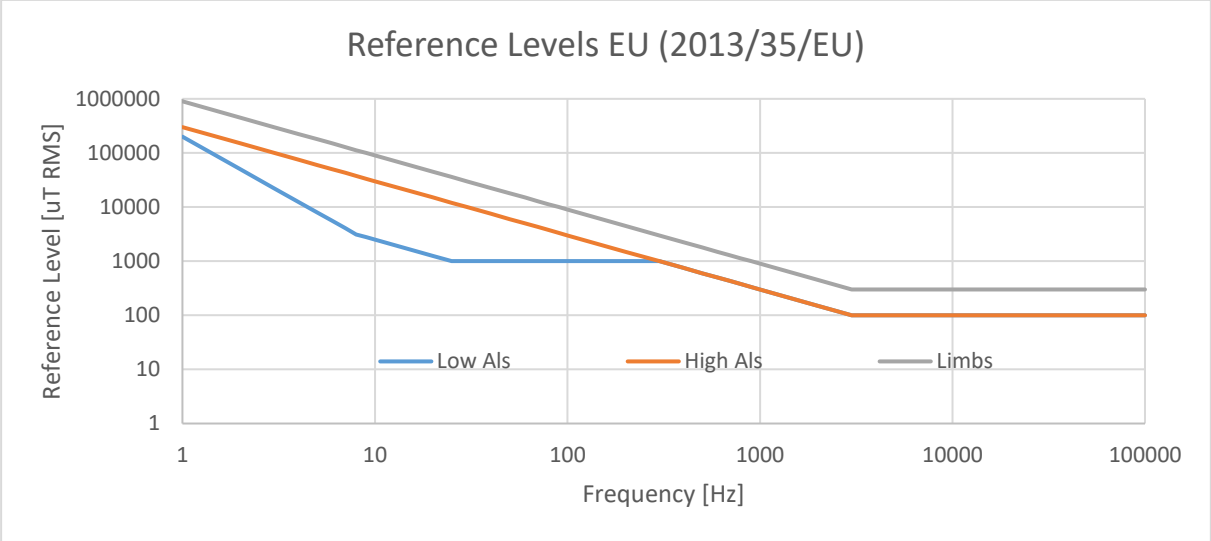

Figure 3: Reference Levels in EU according to 2013/35/EU in the range from 1 Hz to 100 kHz [2].

2.3 Germany

The German reference levels are defined in the EMFV [3]. In contrast to other regulations, the limiting values are given in terms of peak amplitude and not RMS.

By taking this fact into account (scaling by the factor of 1.4), the limits for High ALs (*Obere Auslöseschwelle*) and limbs (*Exposition von Gliedmaßen*) are identical to the corresponding EU levels (see 2.2).

The low AL curve (*Untere Auslöseschwelle*) on the other hand does differ from EU regulation in the range below 8 Hz.

Frequency range	Untere Auslöseschwelle [uT] (peak amplitude)	Obere Auslöseschwelle [uT] (peak amplitude)	Auslöseschwelle für die Exposition von Gliedmaßen [uT] (peak amplitude)
1 - 25 Hz	$3.5 \times 10^4/f$	$4.2 \times 10^5/f$	$1.26 \times 10^6/f$
25 - 300 Hz	1400	$4.2 \times 10^5/f$	$1.26 \times 10^6/f$
300 Hz - 3 kHz	$4.2 \times 10^5/f$	$4.2 \times 10^5/f$	$1.26 \times 10^6/f$
3 kHz - 100 kHz	140	140	420

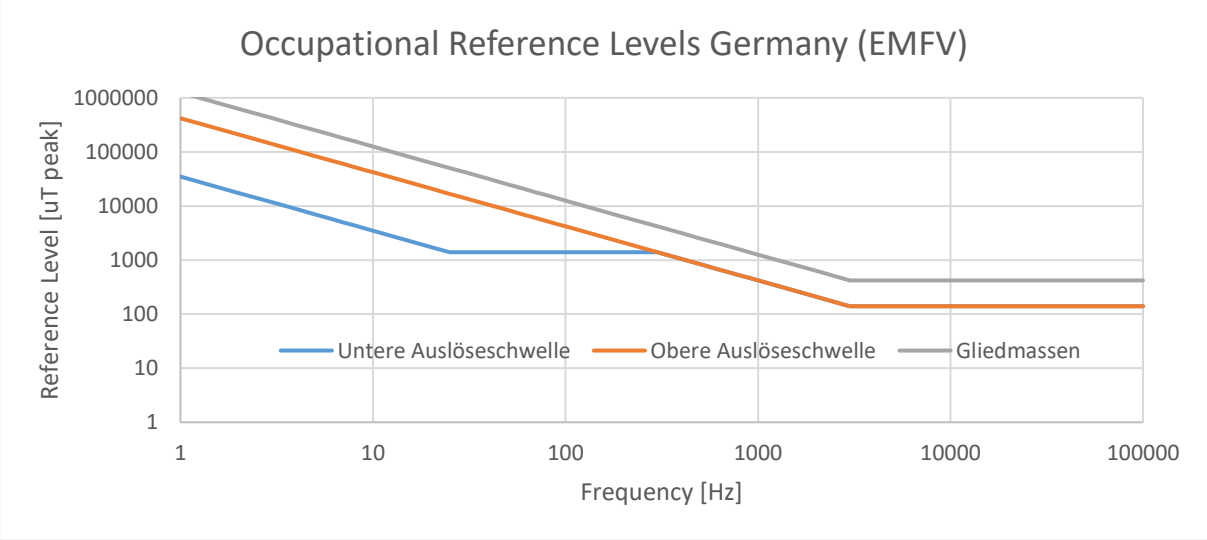

Figure 4: Reference Levels in Germany according to EMFV [3] in the range from 1 Hz to 100 kHz [3].

2.4 Switzerland

In Switzerland the reference levels for magnetic field immissions are defined in the Ordinance on Protection against Non-Ionizing Radiation (ONIR / NISV) [4]. Due to additional safety margins, the Swiss limits are stricter than ICNIRP reference levels.

Frequency range	Magnetic flux [µT] (RMS)
1 - 8 Hz	$2.0 \times 10^4/f^2$
8 - 800 Hz	$5.0 \times 10^3/f$
800 Hz - 100 kHz	6.25

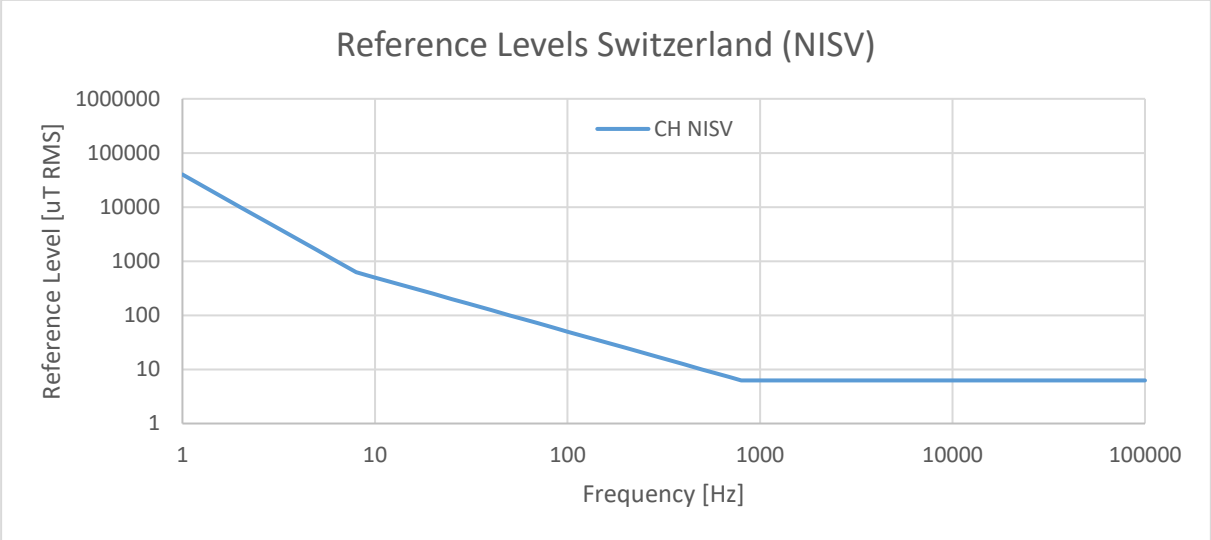

Figure 5: Reference Levels for magnetic field immissions in Switzerland according to ONIR / NISV in the range from 1 Hz to 100 kHz [4]

3 Exposure Index

Everyday magnetic field exposure often consists of a superposition of several sources and frequencies. If several strong frequency components are present in the measured signal, they must be aggregated into a total exposure index. An exposure index greater than 1 signalizes that the limiting values are exceeded. Due to the summation nature of the EI this can happen even when every individual spectral component is below the spectral mask.

The Exposure Index (EI) summation formula represents a linear sum of the weighted frequency components of the measured signal. The weighting factor consists in the field strength of the reference level mask evaluated at the corresponding frequency:

$$EI = \sum_{1\,Hz}^{fmax} \frac{B_i}{BR_i}$$

Because of the high frequency resolution of an ExpoM-ELF measurement, summing over all 1000 frequency bins of a measurement would sum up a considerable amount of sensor noise and therefore yield unrealistically high EI values even when no actual magnetic field is present. In ExpoM-ELF Utility, the EI summation is therefore restricted to the 10 strongest frequency components in the spectrum of the measured signal:

$$EI = \sum_{Peak\ \#1}^{Peak\ \#10} \frac{B_{Peak\ \#i}}{BR_i}$$

In ExpoM-ELF Utility the exposure index of the current measurement is shown in the bottom right corner of the main window. Please note that a mask must be selected in the FFT options (see Figure 6 below) for the EI to be available and displayed.

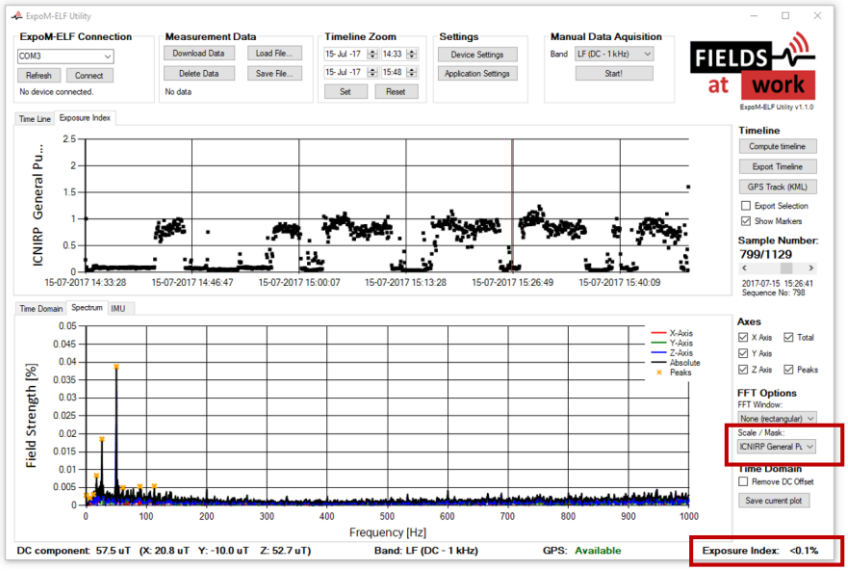

Figure 6: Exposure Index display in ExpoM-ELF Utility 1.1.0

4 References

[1] International Commission of Non-Ionizing Radiation Protection (ICNIRP), “ICNIRP Statement - Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz)”, Health Physics, vol. 99, no. 6, pp. 818-836, Dec 2010.

[2] Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC

[3] Verordnung zum Schutz der Beschäftigten vor Gefährdungen durch elektromagnetische Felder (Arbeitsschutzverordnung zu elektromagnetischen Feldern - EMFV).

[4] Der Schweizerische Bundesrat, "814.710, Verordnung über den Schutz vor nichtionisierender Strahlung (NISV)", 1999 (Stand am 1. Juli 2016).