Low-frequency electromagnetic fields at *31 sleeping areas* in Austria generated by electrical installations and appliances

Armin Rebernig[1,2,3], **Igor Belyaev**[2]*

[1]Pavol Jozef Šafárik University in Košice, 04180 Košice, Slovak Republic · [2]Department of Radiobiology, Cancer Research Institute, Biomedical Research Centre, Slovak Academy of Sciences, Bratislava, 84505, Slovak Republic · [3]Building Biology & Environmental Measuring Technology Rebernig, Engineering Office for Technical Environmental Protection and Building Physics, Graz, 8042, Austria

*Corresponding authors: A. Rebernig (info@bau-biologie.at) · I. Belyaev (igor.beliaev@savba.sk)

31 sleeping areas
AUSTRIAN HOUSEHOLDS

279 data points
9-POINT GRID MEASUREMENTS

100 % exceedance
EUROPAEM 1 V/M NIGHT PRECAUTIONARY

313 V/m max
PEAK ELF-EF AT HEAD REGION

BACKGROUND

In modern indoor environments, occupants are continuously exposed to anthropogenic extremely low-frequency electromagnetic fields (**ELF-EMF**; frequency range **3 Hz – 3 kHz**; mains: 50 Hz in Austria) generated by electrical wiring, fuse circuits, and household appliances [8–10]. Sleeping areas are of particular interest because people spend approximately **2,600–3,300 h·yr^{-1}** in these locations [11,12], in close proximity to wall-embedded wiring and bedside electrical equipment.

While statutory regulatory limits (ICNIRP [21]: 5,000 V/m for ELF electric field, 200,000 nT for ELF magnetic field) are derived from acute thermal and stimulation thresholds, environmental-medicine precautionary values are substantially lower. The **EUROPAEM EMF Guideline 2016** [31] proposes `1 V/m` for nighttime environments and `0.3 V/m` for sensitive individuals; the **NCRP** proposes 10 V/m and 200 nT. In 2002 the IARC classified extremely low-frequency magnetic fields as *possibly carcinogenic to humans* (Group 2B) based on epidemiological evidence on childhood leukaemia [27,28], an assessment reaffirmed by the ARIMMORA consortium [29].

OBJECTIVES

- Quantify **ELF-EF and ELF-MF exposure** at 31 sleeping areas in Austrian households (2024–2026).
- Compare measured values against **EUROPAEM and NCRP precautionary values**.
- Evaluate the efficacy and required effort of **two mitigation strategies**: unplugging local appliances and targeted fuse-circuit deactivation.

METHODS

MEASUREMENT PROTOCOL — VDB-COMPLIANT

ELF-EF grid	Standardised 9-point undisturbed-field procedure across each bed surface
Probe height	10 cm above bed surface, on 5 cm polystyrene block (PS 20)
ELF-MF screening	9-point screening + ≥24 h long-term recording (data logger, head region)
Instruments	EFA-3 (Wandel & Goltermann; 5 Hz–30 kHz, ±5%); EHP-50F/NBM550 (NARDA; 1 Hz–400 kHz, ±0.35 dB); EMLog (ESTEC; 5 Hz–2 kHz, ±3%)
Conditions	Subjects absent; operator ≥1 m from probe; ceiling light off; chargers/transformers *not* unplugged to simulate typical night usage
Mitigation tests	(i) Selective unplugging of bed-proximate appliances; (ii) targeted deactivation of relevant fuse circuits

9-POINT MEASUREMENT GRID (ELF-EF)

1 · head L	2 · head C	3 · head R
4 · mid L	5 · mid C	6 · mid R
7 · foot L	8 · foot C	9 · foot R

Head region · median 17 V/m — **Middle region** · median 13 V/m — **Foot region** · median 4 V/m

Probe spaced 10 cm from vertical surfaces; grid scaled to bed dimensions per VDB Richtlinien [24]. Mains: 230 V / 50 Hz (Austria).

STATISTICAL ANALYSIS

Descriptive statistics, percentile analysis and IQR; log-transformation followed by Shapiro–Wilk normality testing; spatial gradient analysis by region (head / middle / foot); reduction factors computed against baseline maxima.

TAKE-HOME — IN BRIEF

All 31 Austrian sleeping areas exceeded the EUROPAEM nighttime ELF-EF precautionary value (1 V/m); the median maximum value (43 V/m) exceeded it by a factor >40. ELF-MF long-term means stayed below precautionary values except next to railway infrastructure. Implementation of the **final mitigation measures** — deactivation of relevant fuse circuits, alone or combined with removal of appliance-related sources — reduced ELF-EF below 1 V/m at nearly all sleeping areas; appliance unplugging alone was insufficient at every investigated site.

RESULTS

OVERVIEW — ELF-EF EXPOSURE

Across 279 measurement points, ELF-EF values ranged from **0.1 to 313 V/m** (median 5.0 V/m; 75th percentile 13.5 V/m; 90th percentile 38.4 V/m). The distribution was strongly right-skewed and spanned more than three orders of magnitude (Fig. 1). Log-transformed values were consistent with a log-normal distribution (Shapiro–Wilk, $p = 0.08$).

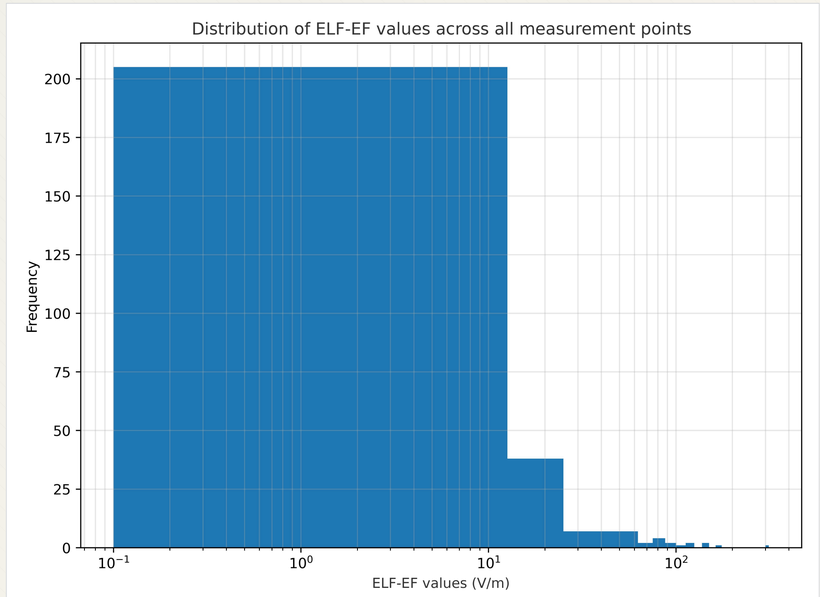

Fig. 1. Distribution of ELF-EF values across all 279 measurement points (log scale). The pronounced right-skewed distribution spans more than three orders of magnitude, indicating substantial spatial heterogeneity of residential ELF-EF exposure.

COMPARISON WITH PRECAUTIONARY VALUES

REFERENCE VALUE	THRESHOLD	EXCEEDED AT
EUROPAEM precautionary — sensitive individuals	0.3 V/m	31 / 31 (100%)
EUROPAEM precautionary — nighttime environments	1.0 V/m	31 / 31 (100%)
EUROPAEM / NCRP precautionary — daytime environments	10 V/m	nearly all areas
ICNIRP statutory limit (50 Hz)	5,000 V/m	0 / 31 (0%)

SPATIAL GRADIENT WITHIN THE BED

Position-specific analysis revealed a **consistent gradient** with systematically higher exposure in the head region than in middle or foot regions (Fig. 2). Median values: **head 17 V/m, middle 13 V/m, foot 4 V/m**; corresponding means: 40.1, 34.2 and 10.7 V/m. Within individual sleeping areas, maximum-to-minimum ratios frequently exceeded one order of magnitude and reached factors of **10–50**.

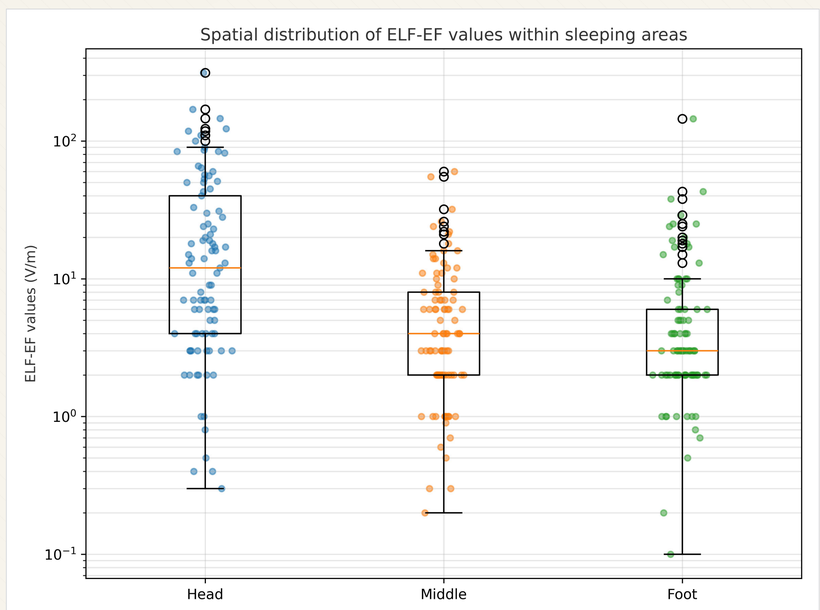

Fig. 2. Spatial distribution of ELF-EF values within sleeping areas. Boxplots with individual data points for head, middle and foot regions. Note the consistently elevated exposure in the head region, where bedside lamps, extension cords and wall-embedded wiring are typically located.

MITIGATION EFFICACY

Selective unplugging of bed-proximate appliances reduced ELF-EF exposure by a factor of **2 to 52** (median ≈ 5×), yet was **insufficient to reduce exposure below 1 V/m at any sleeping area**. The largest reductions were observed after implementation of the **final mitigation measures**, **frequently exceeding two orders of magnitude** and reaching approximately **10^3-fold reductions** in individual cases (Fig. 3). Depending on the sleeping area, the final mitigation measures comprised deactivation of relevant fuse circuits, removal of appliance-related sources, or a combination of both.

A complete mitigation sequence (baseline → appliances unplugged → fuse circuits deactivated) was available for **26 of 31 sleeping areas**; for the remaining five, only baseline and final-mitigation measurements were available. Consequently, the present dataset does not permit a complete separation of the relative contributions of appliance-related sources and electrical installations in all sleeping areas.

Fig. 3. Reduction factors achieved after (i) unplugging local appliances and (ii) implementation of the final mitigation measures. Depending on the sleeping area, the final mitigation measures included deactivation of relevant fuse circuits alone or in combination with removal of appliance-related sources. Individual measurements additionally displayed; *y*-axis on logarithmic scale.

ELF-MF EXPOSURE

ELF-MF long-term mean values ($n = 30$) were generally low — **median 16 nT (90th percentile 30.6 nT)** — and remained **below both EUROPAEM (100 nT) and NCRP (200 nT)** precautionary values at nearly all sleeping areas. One exception (**399 nT**) was observed at a sleeping area in immediate proximity of an ÖBB (Austrian Federal Railways) medium-voltage line, falling within the WHO 300–400 nT range relevant to the IARC childhood-leukaemia classification [27,28]. Log-transformed ELF-MF values deviated significantly from normality (Shapiro–Wilk, $p < 0.01$).

DISCUSSION

ELF-EF exposure in Austrian sleeping environments was characterised by **strong right-skewness, pronounced spatial gradients, and substantial contributions from both building-installation components** (wall-embedded wiring, fuse circuits) **and local appliances**. The relative contribution of these two source classes varied between sleeping areas; the present dataset does not always permit a precise separation, since the final mitigation step in some sleeping areas combined fuse-circuit deactivation with prior removal of appliance-related sources, and a complete sequence was available for 26 of 31 sites.

The median maximum value of **43 V/m exceeds the EUROPAEM nighttime precautionary value by a factor >40**. These findings are consistent with the earlier Lower-Austria household survey by Tomitsch & Dechant (2015) [9] (bedside ELF-EF median 26.2 V/m; max 166 V/m, predominantly from bedside lamps), and with the European ELF exposure review of Gajšek et al. (2016) [34], which highlighted building-technical installations and household appliances as relevant indoor sources.

In contrast, ELF-MF exposure displayed **low variability, no measurable spatial gradient, and stable background-dominated behaviour** — consistent with the spatially highly confined propagation of appliance-related magnetic fields and the large-scale homogeneity of background induction from infrastructure currents. The single elevated case (399 nT, ÖBB line) underscores that ELF-MF mitigation in residential settings is primarily a question of **external infrastructure and shielding**, not of indoor appliance handling.

ELF-EF VS ELF-MF — COMPARATIVE PROFILE

PARAMETER	ELF-EF	ELF-MF
Median (overall)	5–8 V/m	~19–20 nT
Maximum	313 V/m	399 nT
Dynamic range	>3 orders	~2 orders
Log-normality	yes (p=0.08)	no (p<0.01)
Spatial variability	high (head > middle > foot)	low / homogeneous
Main source contributions	wiring + appliances (variable mix)	infrastructure currents
Mitigation: unplug	2–52×	negligible
Final mitigation measures	10–~10^3×	not applicable
Physical mechanism	capacitive coupling	magnetic induction

LIMITATIONS

Sample of 31 sleeping areas; regional restriction to Austria; non-random sample (self-referred clients including preventive enquiries and EMF-associated complaints); single-shot ELF-EF design without temporal long-term measurement; no health assessments.

CONCLUSIONS

ELF-EF exposures at sleeping areas in Austrian households **consistently exceed** the EUROPAEM precautionary values for nighttime environments and sensitive individuals at every site investigated, while statutory ICNIRP limits are substantially undercut at all areas. ELF-MF long-term means stay below EUROPAEM and NCRP precautionary values except in proximity of external high-current infrastructure.

Key practical finding. Implementation of the **final mitigation measures** reduced ELF-EF below the 1 V/m nighttime precautionary value at nearly all sleeping areas. Appliance unplugging alone was not sufficient at any of the 31 sleeping areas investigated. Both local appliances and electrical installations can contribute substantially to ELF-EF exposure, with the relative contribution varying between sleeping areas.

Recommendation. Many relevant ELF-EF exposure sources are technically feasible to address by identifying and mitigating dominant local sources. Exposure reduction is recommended in particular for **vulnerable groups** — children, elderly persons, chronically ill individuals, and persons reporting EMF-associated complaints. ELF-MF mitigation, where required, demands targeted shielding of external infrastructure.

Future work: representative cross-sectional surveys, long-term ELF-EF recordings, and health-related endpoint studies in vulnerable populations.

SELECTED REFERENCES

1. **Belyaev I, Dean A, Eger H,** et al. EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. *Rev Environ Health* 2016;31(3):363–397. doi:10.1515/reveh-2016-0011.
2. **Tomitsch J, Dechant E.** Exposure to electromagnetic fields in households — Trends from 2006 to 2012. *Bioelectromagnetics* 2015;36(1):77–85. doi:10.1002/bem.21887.
3. **ICNIRP.** Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). *Health Phys* 2010;99(6):818–836. doi:10.1097/HP.0b013e3181f06c86.
4. **IARC.** Non-Ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. *IARC Monographs* Vol. 80. Lyon: IARCPress; 2002.
5. **Ahlbom A, Day N, Feychting M,** et al. A pooled analysis of magnetic fields and childhood leukaemia. *Br J Cancer* 2000;83(5):692–698. doi:10.1054/bjoc.2000.1376.
6. **Schüz J, Dasenbrock C, Ravazzani P,** et al. Extremely low-frequency magnetic fields and risk of childhood leukemia: A risk assessment by the ARIMMORA consortium. *Bioelectromagnetics* 2016;37(3):183–189. doi:10.1002/bem.21963.
7. **Gajšek P, Ravazzani P, Grellier J,** et al. Review of studies concerning electromagnetic field (EMF) exposure assessment in Europe: Low frequency fields (50 Hz–100 kHz). *Int J Environ Res Public Health* 2016;13(9):875. doi:10.3390/ijerph13090875.
8. **Virnich MH, Haumann T, Münzenberg U.** VDB-Richtlinien zur Vorgehensweise bei baubiologischen Untersuchungen in Gebäuden, Band 1, 3rd ed. Jesteburg: Berufsverband Deutscher Baubiologen VDB e.V.; 2018.

FUNDING & CONFLICTS

This research received no external funding. The authors declare no conflicts of interest relevant to the content of this article. Measurement data were collected during professional services; clients had no influence on study design, analysis, interpretation, or the decision to publish.

AUTHOR ORCIDS

A. Rebernig — 0009-0009-2077-009X
I. Belyaev — 0000-0002-7963-2240

CONTACT

Dipl.-Ing. Armin Rebernig, B.Sc.
info@bau-biologie.at
Prof. Igor Belyaev, Dr.Sc.
igor.beliaev@savba.sk