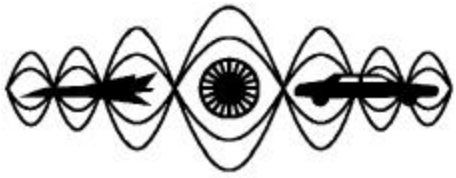

Head-related sound sources and probable health impairing effects by ELF electro-magnetic field emissions

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Abstract: Epidemiological studies about extremely-low-frequency electro-magnetic fields underlined human health impairing aspects. This work demonstrates multiply used headphones/headsets as not only nearfield sound reinforcing devices. Measurements about 100 different headphones/headsets using Pink Noise at 70 dBSPL(C) reveal, that the majority of objects produce a *critical* (see TCO`99) magnetic flux. Furthermore is illustrated a technique to reduce the head-related magnetic field emissions.

1. Introduction - foundations

The fact of a probable health impairing electrical apparatus was discussed more than hundred years ago during the introduction of the electrical light **[1]**. Sixty years later began epidemiological investigations **[2]** on the influence of electromagnetic waves at biological systems. Especially for humans 50 Hz field studies showed a *maximum permissible magnetic field*: ***200 nT*** (nT = nano Tesla, magnetic flux). Based on it the American Commission for Radiation Protection (NCRP) and the TCO`92/‘95/`99 (“sweden standards” for radiationless computer monitors; low-frequencies up to 2000 Hz at 30 cm distance; **[3**) recommends also 200 nT for 50 Hz fields; instead of this the World Health Organization (WHO and IRPA) 100.000 nT(?). Complementary it is to explain a weighting factor in low-frequency field threshold values: For instance the factor “3" is used for a 50 Hz to 16 2/3 Hz field maximum value conversion: The NCRP named 200 nT for 50 Hz would be 600 nT for 16 2/3 Hz **[3]**. But *broad-band electromagnetic fields of audio reinforcement* signals via headphones/headsets are not usable linearly weighted by standardized integrating factors.

This should be done in measuring devices by a rising magnetic flux value equalization proportional to the increasing frequency based on the VDE-DIN draft 0848, part4/A3 (see **figure 1**).
Resulting profound questions are now: Is there any relationship between the above mentioned environmental epidemiological investigations, maximum permissible magnetic field values of the international recommendations and for hours head-related or nearfield used headphones/headsets in call-centers, broadcasting or recording studios or televisions cars? Are to classify headphones, headsets, earsets, hand free sets for mobile telephones really "electro-mag *low* emitting" and without any *probable* human health impairing influence?

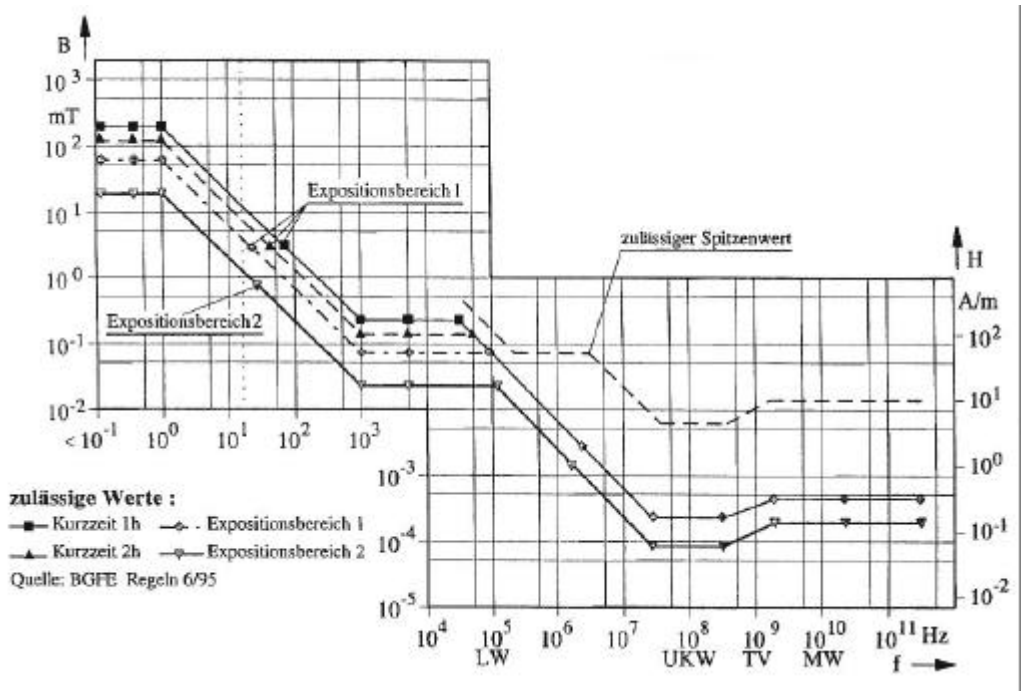

Figure 1: *Exposition area of the maximum permissible magnetic field B or flux H (see marked line by the written German string "zulässiger Spitzenwert") at a influence time of one or two hours as a function of the frequency based on German standards VDE-DIN draft 0848, part4/A3. For example magnetic fields with rising frequencies are permitted with decreasing intensities.*

2. Investigation procedure

Because of the above mentioned "confusion" in low-frequency magnetical field threshold values (see NCRP contrary WHO) it is understandable why headphones for a CE sign or conformation declaration are estimated as “less emitting” so far! To realize measurements of headphones electromagnetic field radiation the first time are existing some main questions about the type of the testing signal, sound-pressure calibration for a mean headphone hearing situation and measuring distance to the transducers. So headphones are nearfield sound reinforcing devices, which are

circum- or supra-aural fixed at the human temple or on the pinna and inside the ear cannel. This includes a special, binaural near-field hearing sense with a head-related headphone to pinna transfer function. All above named facts predict, that the

- test signal should be the same as for ordinary headphone quality tests (see diffuse-field transfer function based on the CCIR 708 via *Pink Noise)*, which also seem to be similar to the statistical spectral probability of a mean audio/music/speech signal,
- volume control, better sound-pressure calibration should have the value near a mean hearing situation level suggested by 70 dBSPL (C weighted, Pink Noise) registered via an artificial ear (coupler) or dummy-head and
- magnetic field (flux) measuring position is at the contact plane of the headphones earpad.

In practice the magnetic field measurement coil must be positioned at the position of the temple with the headphones typical pressure (in N = Newton) recommended with the same mean left to right temple/pinna distance of a standardized dummy-head **(**see **figure 2:** $d_{ku} = d_{ma}$).

The ***research's procedure*** was to calibrate any headphone at 70 dBSPL(C) Pink Noise at first and then to measure the transducers magnetic flux (at minimum two times). For this steps was placed one earcup of each headphone at a coupler and the other one at a distance making board (see **figure 2**, "d_{ku}"). After the calibration were changed the headphones placements to the other device, which includes a magnetic flux measuring instrument and a distance making board (see **figure 2**, "d_{ma}"). There were used a calibrated sound-pressure measuring instrument GOLDLINE type ASA-10B, a magnetic flux measuring device MEDLINE type 60200. This measuring instrument includes three 5 mm small inductivities to registrate 3D field disposition millimeters sensitively near the headphones/headsets miniature speakers (10 x 10 cm measurement coils are integrating the magnetic flux position inexactly). Also was respected the rising magnetic flux value equalization proportionally to increasing frequencies based on the VDE-DIN draft 0848, part4/A3. The ordinary measurement precision was acoustically 20 Hz to 20 kHz +/- 1dB and electro-magnetically 50 Hz to 5 kHz by 10 % (frequency range plus display error including).

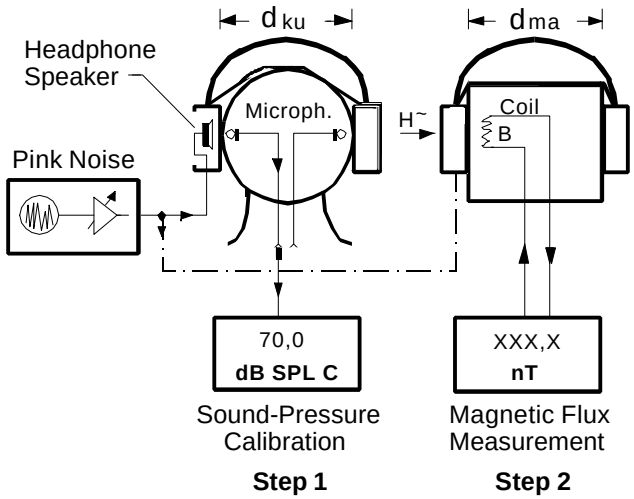

Figure 2: *Headphone calibration at 70 dBSPL(C) via Pink Noise tone signal and measurement of the generated magnetic flux.*

3. Measurement results

3.1 Headphones

After the first research **[4]** including 23 circum-aural headphones of 6 companies now were completed a test field by 60 dynamic circum-aural, supra-aural, cord-less supra-aural, intra-concha headphones and one electrostatic headphone of 16 companies. Beginning with the *electrostatic* type were measured 200 V/m electrostatic field in a distance of 30 centimeters and head-related (nearfield) more than 250 V/m, which was the maximum field advice at the used measuring instrument. A view of the measured magnetic flux mean values of all dynamic headphones types is shown in **figure 3** and **4** (made 1998 and 1999). The measurements were made more times, because there were registered problems to realize a reproducible magnetic flux value, which was based chiefly on headphones with soft ear pad's and a varying pressure (in N = Newton). The fluctuation was near 10 %. So the results of the first investigation **[4]** are supported again via mean declarations at **figure 3** and **4**. The fundamentals of this research are:

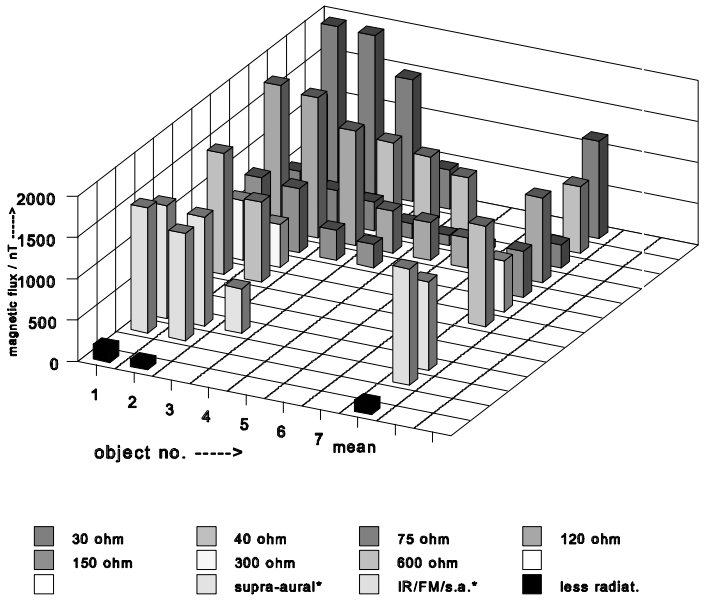

Figure 3: *Measurement results of the generated magnetic flux about 32 dynamic, circum-aural and 5 supra-aural headphones at a reference SPL of 70 dB(C) in 1998.*

- The major circum-aural headphones are working with a higher electro-magnetic field niveau as it is recommended via TCO or NCRP! The mean magnetic flux value is about 845 nT (**figure 3**) at 70 dBSPL(C) Pink Noise. Instead of this the supra-aural headphones got a mean field value at 1620 nT, the FM / Infra-Red headphones 1410 nT and the intra-concha headphones 652 nT (**figure 4**). A total mean excluding circum-aural headphone principles marks 1034 nT.
- The magnetic flux not correlates with the impedance in any probable way.
- Circum-aural headphones have a greater "speaker to temple distance", which caused less fields. Contrary supra-aural headphones (also like cord-less infra-red and FM techniques) produced more than 1000 nT (mean). One special designed supra-

aural headphone with 75 Ohms came to 540 nT. Furthermore is to extract, that the maximum head-near-field intra-concha headphones produced only 652 nT (in the ear channel). The cause will be found at the higher acoustical efficiency to transmit sound waves into the ear channel directly by small headphone loudspeakers (less power and less AC current).

- Only two headphones *without* the intention to realize a "radiation less headphone" having 30 and 75 ohms offered magnetic field values of 130 nT and 125 nT at the borders of the TCO and NCRP (200 nT). Moreover two *extraordinary "radiation less headphones"* **[4, 5]** had a magnetic flux of 90 and 180 nT (75 Ohms) with a headphone internal comparison field reduction of nearly 80 %.

3.2 Headsets, earsets

Based on the experience of chapter 2 and 3.1 were selected main broadcasting and telecommunication headsets/earsets about their magnetic field emissions. This junger investigations included 33 different head-/earsets and two telephone devices of 19 manufactures at the same procedure as before. Regarding the results of **figure 5** is to point out

- a existing a correlation between the magnetic flux value and the acoustics or sound reinforcing principle at the pinna/ear cannel, which is identicly to the earlier circum-/supra-aural headphone investigation results (see only one demonstrated circum-aural type, mean value: 1120 nT).
- Supra-aural headsets having a foam rubber earpad showed higher field desities (mean value: 1446 nT) as same types assembled with a synthetic leather earpad (mean value: 460 nT).
- The two telephone systems were surprising highly emitting magnetic flux near 1130 nT (mean).
- The very **low emitting** devices were

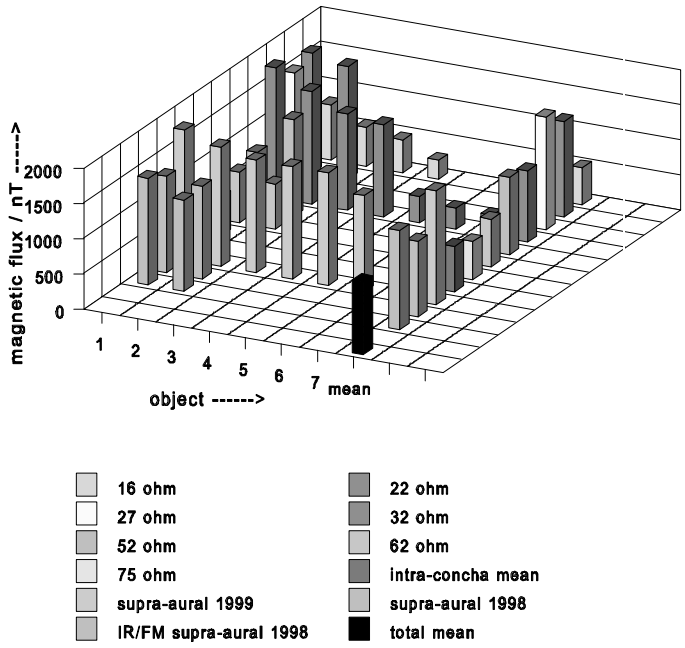

Figure 4: *Measurement results of the generated magnetic flux about 37 dynamic, circum-aural and supra-aural headphones at a reference SPL of 70 dB(C) in 1999.*

intra-cocha and ear cannel earsets with 653 nT and special designed headsets with 50 - 60 nT (**[5]**, see chapter 5; to compare *without* a magnetic flux reducing shield 200 / 630 nT).

- Instead of the telephone system and the circum-aural headsets all head-/earsets had a speaker impedance of 32 Ohms (see chapter 3.1).
- The ***total mean*** about all measured head- and earsets (also hand free sets) is 803 nT (compare with results of 37 headphones in 1998: 840 nT!).

4. Discussion

For the first time to investigate about the radiation of headphones the received results are surprising, because of the unexpected high electro-magnetic fields specifically at supra-aural headphones. If there is any introducing relationship to the basics and recommendations of chapter 2 should produce some variations in the magnetic flux value, but not more than 50 % {see systematic errors or the chosen 70 dBSPL(C)}. About this work and it's respectability is to ask, that

- for a future optimized testing equipment should be available a dummy-head including a measuring coil at the temple or inside it,

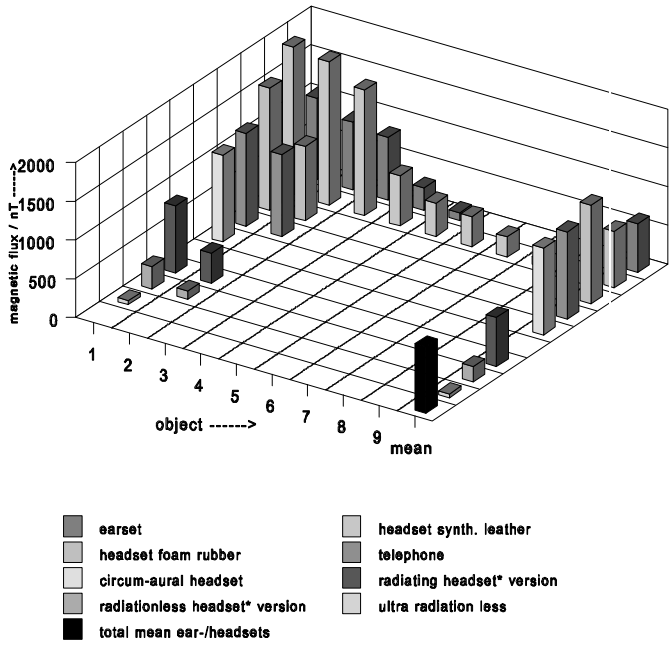

Figure 5: *Measurement results of the generated magnetic flux about 33 dynamic, circum-aural, supra-aural and intra-.concha headsets/earsets at a reference SPL of 70 dB(C) in 2000.*

- further investigations must prove the correctness of the used Pink Noise and 70 dBSPL(C) instead of a realistic mean stimulus like music or speech,
- the chosen 70 dBSPL(C) of broad-band signals were registered strong loudness sensation differences for instance at a telecommunication use (300 - 3400 Hz) and professional audio use (> 20 - 20.000 Hz) based on a speech or music test stimulus, which should force a Pink Noise signal calibrations of headphones/headsets based on the German standard VDE-DIN

draft 45631 (see global loudness calculation) for future comparing investigations,

- tendentially for a 20 Hz to 20 kHz headphone field radiation the NCRP or TCO'95 recommendations having 200 nT should be critically (based on **[3]** to heavy),
- epidemiological health impairing factors must be evaluated because of no experience in such very near-field or head-related magnetic field emitting devices as headphones / headsets. Actually it's not clear how influences magnetic very-low-frequency broad-band fields the brain activities (see EEG measurements for 100 / 217 Hz pulsed mobile telephones and it's health impairing aspects **[6]**).

A systematic error based on wrong not exactly calibrated measurement equipment is to neglect because of facts in chapter 2 and a researches pre-round-robin test including a display adjustment at the Institute of Electrophysics at the University of Munich: The test was realized in a less varying magnetic far-field (and also near-field) condition using a high-power magnet field producing apparatus by a reference measuring instrument GENTRON type el-mag-014 and the above called MEADLINE unit type 60200.

5. Magnetic flux low emitting headphone and headset technique

Before such levels of knowledge updates it seems to be better to reduce the electro-magnetic field emission of electronic systems at first (see the experiences in human "contagan" cases of the sixties). A simple way to do this is made via MU-metal plated buffer-board's inside headphones **[4]**, which is shown in **figure 6**. MU-metal offers a 80.000 times higher permeability compared with only air, which is an alloy of iron, nickel and goblin. This mode to realize a low emitting headphone technique is chiefly combined with developments for a frontal auditory event **[7]**. The main effect in **[5]** is realized by a tongue like a MU-metal bridge or lasered acoustic wholes in front of the speaker coil, which deviates the coil's magnetic field. The above indicated MU-metal plated buffer-board reduced the magnetic flux more than 95 % in comparison to no steps; see results of **figure 3, 4** and one headphone/headset having a field value of 50 - 60 nT. Further steps could be a MU-metal made or sticked at the bufferboard and dust cover in front of the speaker. It is to underline, that the headphones tone quality isn't damaged highly in comparison to constructions without the illustrated steps.

6. Conclusions

Regarding to head-related acoustic systems and accompanying magnetic field emissions near the human brain it was proved the possibility of a headphone/headsets devices **[5]** with very low field emissions. Several headphones/headsets are offering a magnetic flux below the borders of the TCO '95 (200 nT). Perhaps this contribution opens the view to investigate more in consumer electronics, namely the headphones or head-/earsets, which seemed to be "low emitting (not EMC relevant)" before for an eight hours call-center working use ed cetera. Perhaps the received knowledge permits an existing number of "electro sensitiv persons" **[6]** to enjoy a

modern/synthetic made *electro*acoustic exchange: Listening or to communicate without pain in any distance worldwide.

Figure 6: *A bufferboard construction of a low magnetic flux H emitting circum-aural stereo headphone for in front localization (de-centric placed speaker,* ***[7]****) at right pinna having a MU-metal plated/covered loudspeaker system (see diaphragm plus magnet / coil).*

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