Headphones as nearfield electro-magnetic radiator's and probable health impairing objects

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Summery: The progress in electronics and acoustics meanwhile offers spatial auditory events via dynamic (electro-magnetic) or electrostatic headphones. Irrespective of this exists knowledge by epidemiological studies about low-frequency electro-magnetic fields and it's health impairing effects on biological organisms wordwide. A well known result is the "TCO ('95) environmental labelling of displays" or radiation reduced computer monitors and screens. So independent efforts point out, that the TCO idea should be valid also for electronical consumer products. It is to add the nearfield reinforceing headphone? Measurements over 38 headphones gave the answer YES. Using a Pink Noice signal by an ordinary SPL of 70 dBC reveal, that the maior number of headphones produce a electro-magnetical field exposion at human heads, which crosses the border value of the TCO '95. Furthermore will shown steps contra high field values.

1. Introduction and foundations

The main foundations of electro-acoustical reinforce processes are transformations of an a.c. voltage/current component to a sound field. The element for this process is a loudspeaker, which goes back to the electro-magnetic moving coil telephone speaker system of Werner von Siemens in 1877. In the Thirties of this century the electro-dynamic transformation replaced it in headphones and later in the early sixties was coming up the electrostatic transducer. This historical travel back finds his cause in some actual questions: Are headphones similar to "electro-mag" producing devices? Where is to search the reason for the electro-magnetic radiation?

The fact of a probable health impairing electrical apparatus was discussed more than hundred years ago, because of a contest in two different methodes to introduce the electrical light **[1]**: EDISON and HERTZ promoted the *direct current (DC)* and TESLA by the WESTINGHOUSE Company the *alternating current (AC).* EDISON underlined the mortal danger of AC for living creatures. TESLA presented the technical advantages of AC. Otherwise he discovered later, that his "electromagnetic radiations" were healthy (see Schumann-Wave and very-low-frequency magnet-field therapy). Sixty years later were made epidemiological investigations **[2]** on the influence of electromagnetic waves at biological systems. Especially for humans 50 Hz field studies showed significant effects. Apart from systematical and different mistaces in any research became allways the same middle value of a *maximum permissable magnetic-field*: ***200 nT*** (nT = nano Tesla, magnetic flux). This threshold value signes the statistical probability of rising illness rates. Based on it the American Commission for Radiation Protection (NCRP) and the TCO '95 ("sweden standards" for radiationless computer monitors; low-frequencies up to 2000 Hz) recommends also 200 nT for 50 Hz fields; instead of this the World Health Organisation (WHO and IRPA) 100.000 nT! Furthermore the german standard commities worked on a *recommandation for living rooms*, so called VDE-DIN draft 0848, part 4A1/11.90, which includes 100 nT for 50 Hz magnetic fields and electristatic fields 50 to 100 V/m (v/m = Volt per

metre; to compare, WHO: 5000 V/m). Complementary it is to explain a weighting factor in low-frequency field threshold values: 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 are not usable weighted by standardized integrating factors today!

Very new knowledge and theories in the area of electromagnetical field contamination are making a step further: Broad-band currents and voltage can roll up to "current and potential vortex". This vortex's should be the real cause for health riscs at biological creatures **[1]** and accept the existance of a *transversal* and *longitudinal* electro-magnetic wave part, which can have a velocity *more than light* (300.000 km/sec.).

2. Research assembly and realization

Because of the above mentioned confusion in low-frequency electromagnetical field threshold values (see NCRP contrary WHO) it is understandable why headphones for a CE sign or conformitation declaration are estimated as "less radiating" 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 reinforcing devices, which are circum- or supra-aural fixed at the human temple or on the pinna. This includes a special, binaural near-field hearing sense with a head-related transfer function. All above named facts predict, that the

- testing 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/speach signals,
- 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 practic the magnetic field measurement coil must be positioned at the position of the temple with the headphones typical pressure (in N = Newton) recommendated with the same mean left to right temple/pinna distance of a standarized dummy-head (see **FIGURE 1:** $d_{ku} = d_{ma}$).

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. For this steps was placed one earcup of each headphone at a coupler and the other one at a distance making board (see **FIGURE 1**, "d_{ku}"). After the calibration were changed the headphones placements to the other device, which includes a magnetic flux measuring

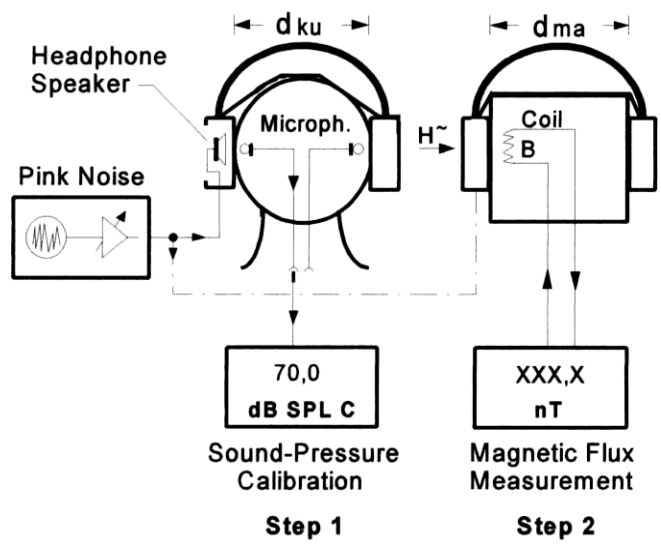

Figure 1: SPL and magnetic flux measurement.

instrument and a distance making board (see **FIGURE 1**, "d_{ma}"). There were used a calibrated sound-pressure measuring instrument GOLDLINE type ASA-10B, a magnetic flux measuring device MEDLINE type 60200. The 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).

3. Measurements and Results

After the first research **[4]** including 23 circum-aural headphones of 6 companies now were completed a test field by 32 dynamic circum-aural, 3 supra-aural, 2 cord-less supra-aural and one electrostatic headphone. Beginning with the *electristatic* type were measured 200 V/m electrostatic field in a distance of 30 centimetres 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 at **TABLE 1:**

ohm's/ circum	30	40	75	120	150	300	600	supra-aural	infra-Red/FM	total mean
flux/nT	1180	810	280	1030	560	620	1220	1075	1410	845

Furthermore all individual headphone type measurements are illustrated in the **FIGURE 2** graphicly. The measurements were made more times, because there were registred problems to realize a reproducable magnetic flux value, which was based chiefly on headphones with soft ear pad's and a variing pressure (in N = Newton). The fluctuation was near 10 %. So the results of the first investigation **[4]** are supported again via mean declarations at **TABLE 1** and **FIGURE 2**. The fundamentals of this research are:

- The maior 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 at 70 dBSPL(C) Pink Noise.
- 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, see **TABLE 1**) produced more than 1300 nT normaly. One special designed supra-aural headphone with 75 Ohms came to 540 nT.
- Only two headphones *without* the intention to realize a

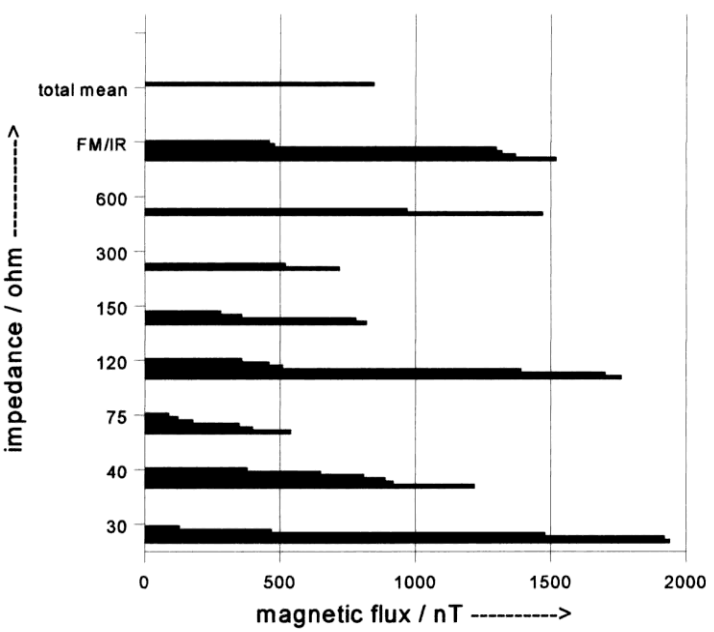

Figure 2: Magnetic flux radiation measurements of 37 dynamic headphones.

"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).

4. Discussion and a *radiation less* headphone solution

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

- for a futur optimized testing equipment should be available a dummy-head with a measuring coil at the temple or inside it,
- 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,
- tendentially for a 20 Hz to 20 kHz headphone field radiation the NCRP or TCO'95 recommandations having 200 nT should be critically (to heavy).
- epidemiological health impairing factors must be evaluated because of the head-related radiating headphone systems. Actually it's not clear how influences magnetic low-frequency broad-band fields the brain activities (see EEG measurements).

Before such levels of knowledge updates it seems to be better to reduce the electro-magnetic radiation at first. A simple way to do this is made via MU-metal plated buffer-board's inside headphones **[4]**. MU-metal offers a 80.000 times higher permiability as air. This radiation less headphone technique is combined with developments for a frontal auditory event **[6]**. The main effect in **[5]** is realized by a tongue like a MU-metal bridge in front of the speaker coil, which derivates the coil's magnetic flield. The above indicated MU-metal plated buffer-board reduced the magnetic flux more than 90 % in comparison to no steps; see table 1 and one headphone having a field value of 90 nT. So it was proved, that are possible headphone devices with a small magnetic flux values below the borders of the german DIN draft 0848, part 4A1/11/90 (100 nT).

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