Extremely low frequency magnetic fields and health risks

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Abstract ***–In a world abounding in artificially created electromagnetic fields, we consider that a new approach regarding their possible harmful effects on living beings becomes mandatory. The paper reviews briefly the results of some epidemiological studies, the ICNIRP (International Committee on Non-Ionizing Radiation Protection) Guidelines and the latest document of the SCENIHR (an organism of the European Commission) regarding extremely low frequency (ELF) magnetic fields. We are convinced that the best conduct that might be adopted on this matter is the policy of the prudential avoidance. Several examples of possible harmful effects determined by extremely low frequency magnetic fields dedicated to building services engineering in residences are presented, along with several methods of mitigating them.***

Keywords: ***EMF, ELF, EMC, stray magnetic fields***

I. INTRODUCTION

The technical world brought an "ocean" of electromagnetic fields and waves, due to circuit boards, cables, data transferring devices, power transmission lines, antennas and highly packed circuits – to mention only a few.

In building services engineering, electrical distribution systems are increasingly powerful, carry more and more harmonic currents, use system earthing arrangements that may have a negative impact, digital communication networks are expanding rapidly, with ever lower electrical levels (a few volts) and ever higher bit rate.

All these claim for the improvement of the cohabitation between high and low currents, which means a proper treatment of exposed conductive parts, of earthing system, shields, mitigating planes, to be chosen and for what purpose, a correct routing of high and low current circuits and many others.

In the broadest sense, electromagnetic research involves three major sources of electromagnetic energy: geofields (generated by the earth, sun and the rest of the cosmos), biofields (generated by living organisms) and technofields (generated by technology).

Since ages people already lived in a natural electric and magnetic field. The value of the natural electric field is time dependent and reaches from 100 V/m to 500 V/m in good weather conditions and from 3kV/m to 20kV/m during thunderstorms. The earth magnetic field has a value of 35μT to 40μT depending on the place on the globe and is time independent too. Due to the continuously existing electric and magnetic field of the earth, it is very important to be able to measure correctly the technically artificial added values of the electric and the magnetic field.

Building services engineering deals mostly with power-frequency electric and magnetic fields (50Hz in Europe), included in a narrow range of the electromagnetic spectrum called extremely low frequency-ELF (3Hz-300Hz). From the energy point of view these frequencies belong to nearly the lowest end of the spectrum – even far lower than the range of radio waves. At 50 Hz and within the considered field levels, there are neither thermal effects nor any ionizing radiation effects.

Until recently, frequencies below the microwave band were assumed to be "biologically safe". But are these fields a sort of uninvited guest for the utilities and the customers?

The European Commission reiterated its opinion that they really are. The latest released study entitled "Health Effects of Exposure to EMF" and adopted by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) at the 28th plenary on 19 January 2009 conclude that extreme low frequency (ELF) magnetic fields are a possible carcinogen and might contribute to an increase in childhood leukaemia and Alzheimer's disease [1].

Unfortunately in EMC literature and EMC regulations both near-field coupling and far-field radiation are lumped under the term radiated emissions.

A distinction must be made between near-field coupling (which is an induced interference) and far field radiation (which is a radiated interference): near-field energy is stored and not radiated. Induced energy coupling has different characteristics compared with radiated energy, high-impedance circuits being very susceptible to interference from electric near fields, and low-impedance circuits, very susceptible to interference from magnetic near fields.

This is not a pure academic distinction, because there are many practical differences between how induced and radiated interference occurs.

Recall just how electromagnetic shields behave in different types of fields. In the near field, electric fields are reflected by a thin metallic shield quite well, whereas magnetic fields readily penetrate metallic shields unless the shield is several depth of penetration thick. The far-field behaviour of shields is different from both magnetic and electric near-field behaviour.

Whereas radiated waves always maintain the impedance of air and are therefore always electromagnetic, near-field waves are usually dominated by one component, electric or magnetic. Near fields that are equal in electric and magnetic fields can be thought of as a superposition of electric and magnetic fields; that is, they do not give rise to any new behaviour[2].

We must also point two extra indirect coupling mechanisms: contact currents that result when the human body comes into contact with an object at a different electric potential (i.e., when either the body or the object is charged by an EMF) and coupling of EMF to medical devices worn by, or implanted in, an individual.

II. POSSIBLE BIOLOGICAL EFFECTS OF ELF MAGNETIC FIELDS

The biological effects of low frequency electric and magnetic fields (EMF) have become a topic of considerable scientific scrutiny during the past decades. There are thirty years since Nancy Wertheimer and Ed Leeper (1979) published the first study suggesting an association between residential exposure to extremely low frequency magnetic fields (EMF) and childhood cancer [3].

A large number of epidemiological studies have focused on two primary populations: children in residential settings and adults in occupational settings. The main cancers associated with EMF exposure are leukaemia, nervous system tumours and, to a lesser extent, lymphoma among children; and leukaemia, nervous system tumours, and breast cancer among adults.

In some epidemiological studies, values of the magnetic flux densities as low as 0.2μT, are mentioned to correlate with significant increase in cancer incidence among populations living nearby power lines [4].

In the International Agency for Research on Cancer (IARC) 2002 evaluation, ELF magnetic fields were classified into group “2B” (“possibly carcinogenic to humans”). Limited evidence of carcinogenicity in humans was chiefly based on epidemiological studies showing a consistent association between magnetic fields above 0.3/0.4μT and the risk of childhood leukaemia [4].

Nevertheless, a cause-effect relationship cannot be inferred. For such moderate epidemiologic associations, data from laboratory studies are usually critical to determine whether a causal link exists. Laboratory evidence should also be complemented by an understanding of the mechanisms via which exposures interact with biological tissues, which has not been identified for ELF exposure.

There are not yet safety standards (issued in terms of biological effects or EMC) regulating the admissible values for power frequency magnetic fields.

Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (EMFs), mentions nothing about general public exposure.

The ICNIRP (International Committee on Non-Ionizing Radiation Protection) Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields, 1998 finds “intriguing” the cut off point of 0.2/0.3μT mentioned in the epidemiological studies as possible carcinogenic, compared to the cut offs of the electric fields.

We find it not at all intriguing, due to the relative low impedance of the human body (generally a homogeneous conductivity of 0.2S/m is assumed), which according to the induced energy coupling characteristics mentioned in the previous section makes humans more susceptible to interference from magnetic near fields than from electric near fields.

But we find intriguing two statements in [5]. On one hand it is mentioned a reference value of 5/*f*μT in the frequency range 0.025–0.8 kHz, which yields 5/50=0.1μT for the 50 Hz magnetic flux density in general public exposure and on the other hand from a graph presented in the same material we find a value of approximately 100μH !? (see Fig.1).

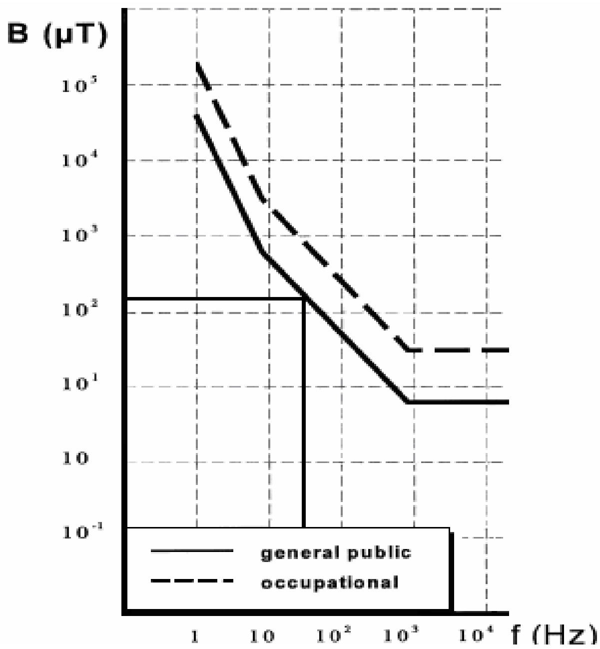

Fig.1 Reference levels for exposure to time varying magnetic fields (source ICNIRP Guidelines 1998)

After all, an essential question rises: it is better to expect the results of medical studies which may extend even decades, and act afterwards, or to adopt from now on a policy of “prudential avoidance” trying to find and apply all the possible solutions for mitigating the influence or these electromagnetic fields? I believe the answer is more than obvious.

III. MEASUREMENTS AND DISCUTIONS

In order to design strategies of field reduction a first step is to know how power frequency magnetic fields are produced.

Using the Biot-Savart formula, the superposition principle and integration one can obtain the magnetic field from a more complex source. The analytic equations are well known from the literature and it is not our purpose to review them here.

Following the principle of the “prudential avoidance” we shall point briefly the sources of magnetic fields in residences, reported as possible carcinogenic, as we have seen in section II and of contact currents, together with some possible cost effective technologically feasible measures to limit EMF exposure.

The Electric Power Research Institute (EPRI) identified the following five classes of residential field sources: electric power transmission lines, electric power distribution lines, ground currents, home wiring, and household appliances.

For the electrical building services engineering the last three are important.

The measurements of the residential magnetic fields were carried out for the RMS values and their components along three orthonormalized reference axes (x,y,z) using the CA42 low frequency spectrometer (Chauvin Arnoux).

If n is the frequency, the RMS values on each reference axes of a signal having N frequency components are respectively:

$V_{eff}\left(x\right)=\sqrt{\frac{1}{N}\sum_{n=1}^{N}x\left(n\right)^{2}}$, etc. and the global RMS value of the resultant is:

$$V_{eff}\left(x,y,z\right)=\sqrt{V_{eff}\left(x\right)^{2}+V_{eff}\left(y\right)^{2}+V_{eff}\left(z\right)^{2}} \qquad (1)$$

Power is carried from distribution transformers on secondary distribution lines. Service drops to each customer are connected normally to the secondary distribution lines.

The most common type of cable configurations installed in houses and connected to electrical appliances contains two parallel conductors carrying opposite currents. These conductors are close to each other and the total magnetic field, in principle, nearly cancels (a similar statement is valid for cables).

However, in practice, this is not always true because of the existence of net currents on some distribution lines [6].

For example, three-way and cross switches are used where it is desired to control a load from multiple points. The most common applications are lights that can be turned on/off in the different levels of a stairway, or at the entrance in bedrooms and near the bed.

Fig. 2 shows two alternative ways that an installation could be made to control a light from two different switches.

In the lower diagram, the various wires are routed in multi-wire cables so that the net current in any of the cables is zero. Consequently, the magnetic fields from the conductors in any cable largely cancel, with the result that this installation would not be a significant source of residential magnetic fields.

A different installation-one requiring less total wire- is shown in the upper panel of Fig. 2. Here, a separate wire is routed from each switch directly to the light, and the direct connections between switches are made with a two-wire cable. However, this cable, and the wires connecting to the light, will carry a net current-the entire current required to energize the light. If these two elements are separated significantly, the magnetic field in their vicinity could be significant.

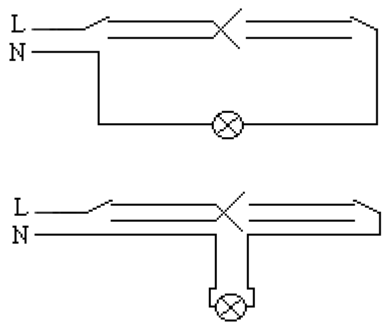

Fig. 2 Electric light control with three different switches

The authors have studied a home where turning on a hall light raised the field from about 0.05µT to 0.6µT and in a hall with a correct wiring the magnetic field remained unchanged.

The repartition of the measured values in the two situations is presented in the form of histograms in Fig. 3.

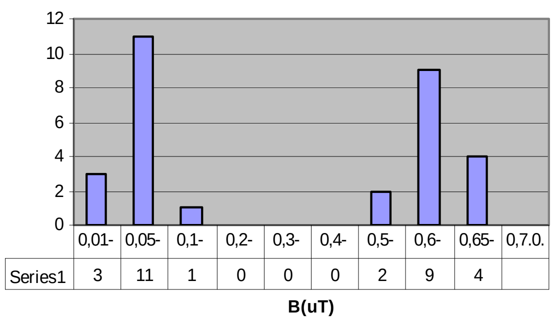

Fig.3 Magnetic field density in the two situations

It can be seen that with the 180W lamps turned off the most of the measured values are around 0.05µT and with the lamps turned on the most of the measured values are around 0.6μT.

Stray currents are one of the most common sources of magnetic fields which represent electricity that is not contained in wiring; these are currents that escape from an intended electric circuit and return. Such currents may run along pipes, and spread even to neighbouring houses, instead of staying along the neutral conductor, which is intended to carry the current back to the feeding system. This problem is common in four wire systems.

An interesting characteristic of stray currents is that they are not possible to mitigate using conductive shielding, since induced currents need a returning path. Neither can they be passive or actively compensated for similar reasons.

A solution to it is to add an extra cable (five-conductor system), which will give the current a direct return path to the ground of the feeding system, without dividing or spreading.

Apparently home appliances are not in the charge of the building services engineering. But the right location of heating centrals and water boilers, of air conditioned splits etc. is really very important, not only from the functional point of view but also for magnetic fields exposure avoidance. When metallic enclosures are poorly designed, the near field of signals can extend further than necessary creating the so called stray fields.

We speak here about near fields and as we have stated in section I that near field magnetic fields readily penetrate metallic shields unless the shield is several depth of penetration thick.

For near-field electric sources, reflection loss is predominant at the lower frequencies, while absorption loss is predominant at the higher frequencies.

Absorption loss tends to be the dominant shielding mechanism for near-field, magnetic sources at all frequencies. However, both reflection and absorption loss are quite small for near-field, magnetic sources at low frequencies.

Using Maxwell equations for x axis it can be derived:

$$\frac{\partial^2 \underline{B}}{\partial x^2} - j\omega\mu\sigma\underline{B} = 0 \quad (2)$$

to which the general solution is

$$\underline{B} = C_1 \exp\left(\sqrt{j\omega\mu\sigma x}\right) + C_2 \exp\left(-\sqrt{j\omega\mu\sigma x}\right) \quad (3)$$

Applying the boundary condition and defining the field at the surface of the interface as $B(x \to \infty) = 0$ and $B(x = 0) = B_0$:

and introducing the penetration depth δ, the solution becomes:

$$\underline{B} = B_0 \exp\left[-(1+j)\frac{x}{\delta}\right] \quad (4)$$

The authors have measured the stray magnetic field generated by an apartment gas heating central (24kW heating power, steel enclosure, 1.5mm thick, 1.8 mm penetration depth for μ_r =200) placed right near the kitchen table. During the heating process of the water in the 60*l* boiler, the ELF magnetic field values raised up to 19μT. The decay of the RMS magnetic flux density versus distance (in m) is presented in Fig. 4; the calculated values are represented on the lower curve and the measured ones on the upper curve. Obviously in that case the location of the heating central was a wrong one.

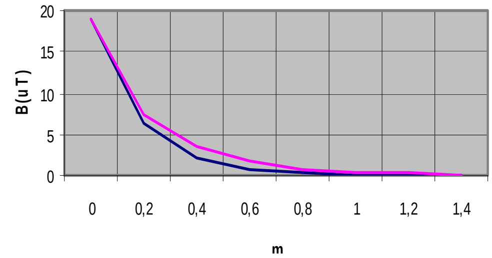

Fig. 4 Magnetic flux density versus distance

The contact or "leakage" current is a current flowing through the body that appears when two members of the body are in contact with two metallic parts subject to a different potential. It is thus linked to a potential difference called contact voltage.

ICNIRP Guidelines specifies 0.5mA contact current limits for the general public.

IV. CONCLUSIONS

The authors have become increasingly convinced that electric and magnetic fields do affect living systems. It is obvious also that these effects vary with individual sensitivities, with geography as influenced by the earth's magnetic field, and with daily and seasonal cycles, that they can occur at low frequencies and low intensities and that the scientific community is very close to understand several of the mechanisms involved.

We are convinced that soon we shall better understand certain disorders and will learn to treat these and other ailments, for which we currently lack the tools.

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