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COMPARING EXAMINATION OF ELECTROMAGNETIC FIELD LEVELS IN DOWNTOWN APARTMENT HOUSES WITH FLATS IN HOUSING ESTATES

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Abstract

In Budapest the housing stock mainly consists of old apartment buildings and housing estates from prefabricated reinforced concrete slabs. This paper gives a comparing examination on the electromagnetic field levels measured in these homes. The results show that average value in electric fields and magnetic fields in flats in housing estates are half of the values measured in apartment houses. Power flux density in flats in housing estates is ten-twenty times greater than in old apartment houses. However, values in the above mentioned flats are below the limits set by ICNIRP, the difference is interesting and can be explained by architectural reasons.

Keywords

electromagnetic field levels, measurement, comparison, standards, protection

1. Introduction

I have heard many times somebody complaining that the cell phone is not receiving signal in every corner of the apartment. Most of these people were living in downtown Budapest in an old apartment building. Previously I have experienced that the electric and magnetic radiation levels on extremely low frequency (ELF) are higher in old apartment buildings.

Buildings built in Budapest before 1946 gives 80-100% of the housing stock in the inner districts and 60-80% in the middle districts. The result of building housing estates from prefabricated reinforced concrete slabs beginning in 1970 is that today these types of flats give the 24% of the housing stock in Budapest, and the flats built after 2000 which are present in different proportions in different districts, give about 20% of the housing stock. From these numbers it is clear that the housing stock contains mainly old apartment buildings, and the other great number of flats is in housing estates from the '70s and '80s. For the above mentioned reasons I have decided to take measurements in these two types of flats, and find out the major differences, and the possible reasons what can cause different electromagnetic levels in the same city.

2. Measurements

The measuring tool I used for low frequency is Gigahertz Solution NFA 1000. This is a 3D analyser between 5 Hz and 1000 kHz. I performed two rounds of measurements in each apartment, first I measured the electric field levels, then the magnetic field levels, walking round in the room first by the walls, then in the middle. I placed particular attention on the beds, since this is the place where a person stays still for the longest time trying to relax. In this measurement series the focus was on radiation levels from wiring and household appliances so the frequency was fixed on 50/60 Hz both when measuring electric and magnetic field levels. I draw a floorplan in advance for each flat and noted the measured values on the spot where the measurement was taken.

I have used Gigahertz Solution HF59B High frequency analyser with a triangular antenna for 800MHz-2,5GHz. With this tool I walked slowly around the room turning around many times to observe what the direction of the highest irradiation is. I marked the directions with red arrows on the floorplan and noted the value next to it. Since my main interest was on the effect of outside or uncontrollable sources I always asked the owner to turn off the wifi router if there was one present. In most cases the direction of the irradiation was towards the façade wall, and in some cases towards a neighboring wifi router.

When evaluating I separated the values into minimum, main, and maximum values. Main value means the average of the most frequent values. In extremely low frequency (ELF) the median of the electric fields measured at the Living room of the 10 old apartment buildings is 16.5, 32, 101 V/m (minimum, main, max). The median in the block of flats buildings is 0.65, 12.88, 51 V/m (minimum, main, max). The median of the magnetic fields is 36, 44, 63nT, while in the block of flats 19.64, 22.4, 32.7nT. The median of the electric fields measured at the Bedroom of the 10 old apartment buildings is 20, 43, 111 V/m (minimum, main, max). The median in the block of flats buildings is 1.82, 7.57, 27.93 V/m (minimum, main, max). The median of the magnetic fields is 41, 42, 61nT, while in the block of flats 16.2, 19.5, 24.1nT. All values in the old apartment buildings are at least the double of the values in the block of flats buildings (Table 1).

The evaluation of the high frequency (HF) measurements gave the opposite results. In this frequency the medians of the electromagnetic levels in the Living rooms are 2.2, 3,9 $\mu W/m^2$ (main, max) in the old apartment buildings while 11.5, 96.34 $\mu W/m^2$ (main, max) in block of flats buildings. In the bedrooms these values are 1.05, 4.24$\mu W/m^2$ and 12.5, 59.36 $\mu W/m^2$ respectively. In the old apartment buildings the power flux density is basically the tenth of the power flux density in flock of flats buildings (Table 2).

Table 1. The measured electric and magnetic field levels

	Electric field levels in Old apartment houses										Block of flats in housing estates					
	1	2	3	5	6	8	9	10	11	Med	1	2	3	4	5	Med
Livin g	19	30	14	7,8	8,8	40	10	31	23	**16,5**	6.2	0.2	0.3	0.6	0.7	**0.65**
	34	30	15	21	19	75	80	45	33	**32**	30	12	1,7	2,1	23	**12.88**
	82	151	97	115	72	208	104	98	67	**101**	48	12,5	111	28	71	**51.05**
Bed room	20	17,3	22	5,7	16	5,4	26	54	26	**20**	3,6	0	0	8	1,1	**1.82**
	33	36	68	20	24	47	85	123	43	**43**	7,4	7,2	1,1	10	13	**7.57**
	61	245	200	72	99	485	103	310	111	**111**	9,3	32	30	13	45	**27.93**
	Magnetic field levels in Old apartment houses										Block of flats in housing estates					
	1	2	3	5	6	8	9	10	11	Med	1	2	3	4	5	Med
Livin g	59	20	36	48	17	59	22	8	10	**36**	8	16	27	56	9,4	**19,64**
	65	40	42	52	28	77	33	14	18	**44**	14	19	27	56	13	**22,4**
	82	60	66	57	36	134	36	19	28	**63**	18	24	83	67	15	**32,7**
Bed room	56	42	28	41	26	52	58	8	27	**41**	12	14	19	36	11	**16,2**
	56	42	33	42	32	52	94	10	31	**42**	14	16	19	36	20	**19,5**
	79	74	55	64	38	188	192	10	41	**64**	16	29	20	44	22	**24,1**

Table 2. The measured Power flux density

	Old apartment houses										Flats in housing estates					
	1	2	3	5	6	8	9	10	11	Med	1	2	3	4	5	Med
Li vi	2,2		30	2	2,4	4,6	2,8	1,02	0,38	**2,2**	0,4	5	68	1,8	18	**11,5**
	4,6		108	3	3,8	8	4,9	2,67	0,93	**3,9**	0,4	90	176	109	98	**96,34**
Be d			30	12	5	0	0,4	1,05	0,79	**1,05**	2,9	13,9	12	13	18	**12,5**
			93	20	10	1,6	6,5	1,98	0,86	**4,24**	9,6	32	110	190	42	**59,36**

3. Reasons

Structural reasons

There are some major structural differences between an old apartment building, and a block of flats building. First of all the material of the walls are different. The old apartment buildings are made of solid bricks, the block of flats building is made from prefabricated reinforced concrete slab panels. I have made simulations using CST Microwave Studio to observe the difference in behavior in these situations. CST Microwave Studio is a tool that rigorously solves the governing equations of electromagnetism, Maxwell's equations, for any situation given. It does that by making use of powerful numerical techniques, in this case the Finite Integration Technique. The characteristics used for this material in the simulations are coming from the material library in the electromagnetic simulation software used: CST's "one year old concrete", and "brick". The real part of the permittivity for concrete is 5.608 the imaginary part is 0.217, for brick the permittivity is4.64 the conductivity is 0.02 S/m which is in agreement with the values in literature [1, 2]. Simulations were performed on a small room with outer dimensions 5.0 m x 3.6 m x 3.3 m. Results show that the electromagnetic level inside a room where the walls are made of bricks is lower than the same room with concrete walls (Figure 1).

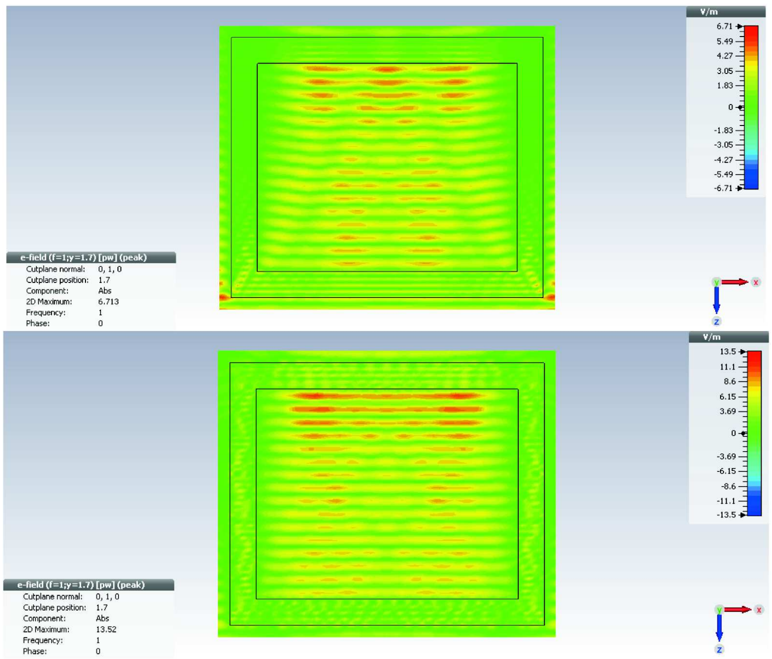

Figure 1. Field levels in a simulated room made from brick (top) and concrete (bottom)

The second difference is that not only the material, but the thickness of the walls is different. It is common that the wall of an old apartment building is 51-64 cm thick, while the thickness of a concrete panel is only 25-30 cm. These panels include mineral or polystyrene insulations, but for simplified simulations I have only considered homogenous walls with different thicknesses. Results show that thicker walls have higher attenuation (Figure 2). Attenuation is expressed in shielding effectiveness (SE) as the ratio of the external field to the internal one in decibels:

$$SE = 20Log\frac{|E_{ext}|}{|E_{\text{int}}|}$$

Attenuation was found in the simulations 4.73 dB and 10.17 dB by 30 and 50 cm thick solid brick wall respectively.

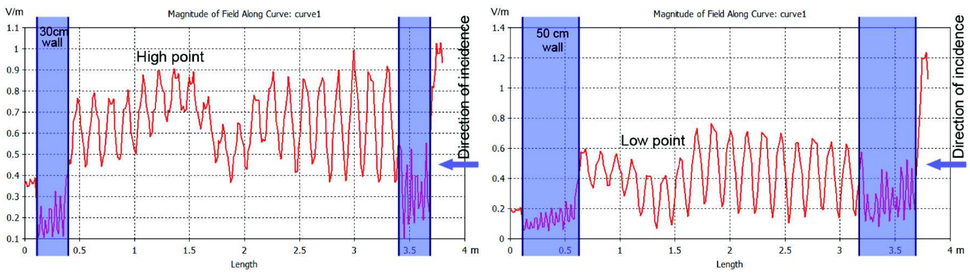

Figure 2. Magnitude of field in the section of the simulated rooms with 30 (left) and 50 right cm thick wall

The third major difference is in the size of the windows, and the proportion of the windows and the wall. Since the inner height of these old apartments is around 3.80 meter, the shape of the windows is a horizontal rectangle. The width of these windows is usually 1.20 the height is 2.30 meter. The proportion of the opening (window) to the wall is 20-29%. The inner height of a flat in a housing estate is around 2.70. The windows are located in the centre of the panel, or the windows (almost) fill the whole width of the room. The width of the windows differ, the height is usually 1.50 meter. The proportion of the windows and the front wall in these flats is 32-44% which is 62-65 percent bigger than in old apartments (Table 3).

Table 3. Proportion of wall and windows in a façade wall of a room

Location	Room width	window size	Proportion of the wall and windows
Old apartment house, Bedroom	3.6	1.20 x 2.30	20%
Old apartment house, Living room	5	2 x 1.20 x 2.30	29%
Block of flats, Bedroom	2.6	1.50 x 1.50	32%
Block of flats, Living room	3	(0.9+1.50)x1.50	44%

I have run simulations were the material properties of the glass were: permittivity 4.82 and tangent delta 0.0054. The tangent delta is the parameter describing the losses in the material. These tests verified that the results with glass or without glass are essentially the same. Thus non-shielded windows behave as just openings. Conclusion is since “common” window glass itself doesn’t shield due to its material properties and thinness, the greater the proportion of the windows to the wall, the less attenuation is given to the room.

Thicker walls made from brick, smaller window-wall proportion make the old apartment buildings more resistant to high frequency radiations.

Local reasons

In ELF the spatially most extended outdoor sources are high-voltage overhead power lines used for the transmission and distribution of electricity, including the feeder lines for electric vehicles like trams and commuter trains. There are approximately 360,000 km of overhead transmission power lines in the EU at voltages of between 110 - 750 kV [3]. A smaller country like Hungary has approximately 3,800 km of these lines. Very few electric power transport system is supplied by underground cables (2%), against the fact that electric field is negligible and magnetic fields are significantly lower next to the cables, but on the line itself the field can be higher [4] According to the actual GKM [5] decree the clearance from a 120kV power line should be 13 m in Hungary. In buildings in a 25m distance I have measured 830nT which is approximately 15 times greater than in other buildings where there are no power lines around.

Urban structural reasons

For mobile communication networks the lowest power flux density values were found at ground floor, and the highest values were detected in category above the second floor [6]. One reason is that higher floors are more often in line of sight to mobile phone base stations and in the main lobe of the antenna resulting in higher power flux densities. The other reason is that the distance between the high-rise buildings -due to fire security reasons- are greater, what makes it possible for the antenna to radiate directly towards the opposite building. In downtown the buildings are in most cases three-four maximum five story high. The height of these buildings is equivalent with the height of 4-5 story high building in a housing estate. These buildings are not just lower than the in most cases 10 story high buildings in a housing estates, but they are closer to the opposite buildings in this case the transmitter antennas radiate in a certain angle to cover more area of that street, not directly facing the building.

Near future technologies

One of the most interesting news in last year that might bring a big change in the ELF was the announcement of wireless electricity [7]. The technology uses a coil of electrical wire that generates a magnetic field, and if another coil is brought close electrical charge will be generated. The developers now work on increasing the distance so that power can be transferred efficiently. If this technology is used all over the house that will possibly raise the level of the magnetic field in it.

As for the HF, studies have shown already that the median of mobile phone downlink signals doubled from 2006 to 2009, and continued to increase due to further growth mainly in UMTS base stations [6, 8]. New types of network architectures based on small cells will be needed to offload traffic. 5G wireless systems are in the doorstep. This will lead to more access points and transmitters radiating from more directions, and it will bring the access point closer to the user. In frequency usage, there are networks which already work on 5 GHz, instead of 2.4 GHz, Scientists are facing many changes! New architectural, urban structural studies have to be made, to examine the changes in reflection, absorption and power density levels.

4. References and recommendations

For each frequency domain, the ICNIRP have limited the exposure levels. Regarding 50 Hz fields, the ICNIRP reference level for the electric field is 5000 V/m and the reference level for the magnetic field is 200µT [9]. The EU issued a recommendation in 1999 concerning restrictions on the exposure of the general public to electric and magnetic fields. Restriction is 100µT for magnetic fields [10]. In many EU countries, these values are recognized, but some national or local governments have issued their own stricter exposure guidelines, like in Belgium the restriction for magnetic fields is 10µT. The values from measurements are below these levels, however, the Building biology standards recommend even stricter limits, saying "any risk reduction is worth achieving. Nature is the ultimate standard". They recommend less than 5 V/m, and 20nT in ELF (sbm2008) If one wants to meet these recommendations, there are some simple steps that can be done.

The main ELF sources of exposure for the general public are from household and similar electric appliances. In ELF-EFs and ELF-MFs can be reduced the easiest by distance keeping, because exposures from these devices are localized and strongly depend on the distance from the appliance. In existing buildings, reorganizing the room, changing the position of the bed, or removing alarm clocks with radio, metallic lamps, and extension cables from under and around the bed will significantly reduce the level of electric and magnetic fields. Renewing the whole electric system is an expensive choice, but it is strongly advised in old flats, where in most cases the electric system is not grounded. By changing the electric wiring to modern shielded (foil or braid) cables will reduce the electric fields. One of the outcomes in the measurements taken in different homes is that electric and magnetic fields in homes with not grounded electric wiring were 3-4 times higher than in homes with grounded electricity (Table 4).

Table 4. Examples for electric and magnetic field levels in grounded and not grounded homes

	Location	magnetic field	electric field
Not grounded	Dohány u 84	77-157 nT	68-88 V/m
	Brody Sándor u 36	45-90 nT	56-116 V/m
	Brody Sándor u 17	33-40 nT	98-150 V/m
Grounded	Hunyadi tér 1	18-28 nT	23-33 V/m
	Zoltán utca	20-21 nT	5,1-6,1 V/m
	Garay tér 11	19-26 nT	19-29 V/m

As for the high frequency, the power density limitation is 10 W/m2 for the general public [9, 10] The measured values are way below this level but again, if we take the building biology recommendations into consideration, the numbers are not so satisfying. There are some other recommendations like EU-Parlament STOA: 100µW/m^2, or in Salzburg the indoor limit is 1µW/m^2.

Since 2008 it is possible to buy cordless telephones with LR mode, which only emits radiation during active telephone calls. This option is not activated by default, but activating this mode the median of DECT radiation can decrease by 24% [6].

Checking for the available wifi networks on the mobile phone showed many times that six or more networks are present with different signal strengths, which mean that the flat is irradiated from more directions. Using wifi routers with sleep mode would turn off the signal at night when nobody uses the network. There are options to shield our flat from outside sources, for example carbon based wall paints. My simulations have shown that if only the walls are shielded the power density from radiation through the windows can be even higher inside than it was before. Therefore shielding the windows is one important step.

5. Conclusion

Architectural design has effect on the inside electromagnetic levels. Thoughtfully designed buildings where the electromagnetic effects are taken into consideration can reduce field levels, and help propagation. There are simple steps that the resident can do to make the flat harmonized. The wireless communication technology improves rapidly, architects, scientists working in the field of electric engineering and wireless communication have to be aware of the effect of their profession on the other disciplines, and have to work together to build the city of the future.

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References

[1.] Shah M. A., Hasted J. B., Moore L.: 1965. Microwave absorption by water in building materials: Aerated concrete. British J. of Applied Physics, Vol. 16, pp. 1747-1754

[2.] Sou C. K., Landron O., Feuerstein M. J.: 1992. Characterization of electromagnetic properties of building materials for use in site-specific propagation prediction, Mobile Portable Radio Res. Grp. (MPRG) Tech. Rep. 92-12, Virginia Tech.

[3.] ENTSO-E Statistical Yearbook.: 2009.

[4.] ICF Consulting.: 2003. Overview of the Potential for Undergrounding the Electricity Networks in Europe, Final Report for the DG TREN-EC.

[5.] GKM.: 2011. 122/2004. decree (X.15)

[6.] Tomitsch J., Dechant E.: 2015. Exposure to Electromagnetic Fields in Households – Trends from 2006 to 2012, Bioelectromagnetics, Vol. 36, pp.77-85 http://dx.doi.org/10.1002/bem.21887

[7.] CNN.: 2014. Wireless electricity? It's here by Nick Glass and Matthew Ponsford. CNN, 2014.
[8.] Kurz T., de Ridder M., Becker C.: 2013. EMF –Monitoring in Bayern 2011/2012. Bavarian Environment Agency
[9.] ICNIRP.: 2010. Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz TO 100 kHz), International Commission on Non-Ionizing Radiation Protection. Health Physics, 99:818-836.
[10.] EU Council.: 1999. European Union, Council Recommendation, of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC), Off. J. Europ. Comm., L 199/59.