CHALMERS

Magnetic Field Measurement in Residential Areas

Göteborg, Borås and Mark Residential Area Measurements

Master of Science Thesis in Biomedical Engineering

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Abstract

All conductors carrying electricity produce a field of force around them called magnetic field therefore increasing use of electrical equipments means there is increased exposure to magnetic fields.

Concerns regarding health hazards due to exposure to low frequency magnetic fields arise, due to this reason it is of great importance to know about the distribution of the magnetic field in residential area. In Sweden Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority) asked Chalmers University of Technology in Gothenburg to perform a study in Gothenburg, Borås and Mark in order to provide the Authorities with magnetic field distribution in the houses in these areas, for this purpose a total number of 97 houses were chosen randomly in Gothenburg, Borås and Mark to measure the magnetic field in them.

Mainly two types of measurements were performed in each house, first single point measurements in the living room, bedroom and kitchen in 15 different points in 3 different height levels in each of the mentioned rooms, accompanied with 24 hours measurements in the master bedroom. Finally the readings from both measurements were combined to calculate the average magnetic field of each house and also the average magnetic field exposed to people in each house based on the average time they spend in each room.

This study revealed that 90% of these houses had an average magnetic field in the range 0-0.2 μT with the median value of 0.05 μT and mean value of 0.1 μT which is very close to average magnetic field exposed to people in each house, while the average magnetic exposed to people has the mean value of 0.12 μT and median of 0.05 μT. The reason behind this similarity was due to similar variation of the magnetic field during 24 hours in all the rooms of the house.

It was also aimed in this study to include some information regarding harmonics forming the magnetic field in each house and include some information regarding the total harmonic distortion (THD). It was observed that that most of the houses have high values of THD. One reason could be due to more non-linear loads in the houses.

Beside these main observations some other information regarding the distribution of the magnetic field based on different concepts are included in this study.

Grouping houses based on villa or apartment revealed that the apartments have higher magnetic field values comparing to villas.

In another approach all the houses were divided between three groups, big city, small town and other (countryside) and it was observed that magnetic field in the countryside is less than in the other two groups.

Finally it was observed that the magnetic field has its highest value at the bottom floor level of most rooms.

Contents

List of Abbreviations:

CDF: Commutative Distribution Function
EMF: Electric and Magnetic Field
ICNIRP: International Commission on Non-Ionizing Radiation Protection
IARC: International Agency for Research on Cancer
LS: Largest Signal
NIR: Non Ionizing Radiation
RMS: Root Mean Square
THD: Total Harmonic Distortion

Report Outline

This thesis work is aimed to give a distribution of the magnetic field for the houses in Gothenburg, Borås and Mark in Sweden.

In chapter 1 magnetic field and different sources of magnetic field are introduced then electromagnetic spectrum is analyzed and health hazard associated with non ionizing part of the spectrum are reviewed.

In chapter 2 methods used in this study for measuring the magnetic field are described as well as the instruments used for the measurement purpose then at the end different measurement metrics used to express the results are explained.

In chapter 3 results of this study are presented. As the final goal of this study a Cumulative distribution function (CDF) is represented which shows how many percent of the houses are below a certain magnetic field level.

In chapter 4 a discussion on the final results is held.

Chapter 1

1. Introduction

This chapter is aimed to provide the reader with the definition of the main concepts used in this study and beside that explain the main reasons for conducting this study.

1.1 Magnetic Field

Magnetic field is defined as "a field of force produced by moving electric charges or by elementary particles that possess their own 'intrinsic' magnetic field" [1].

Among different sources indicated in former definition of the magnetic fields in this study we are interested in the magnetic fields produced by conductors carrying electricity.

Magnetic fields produced by electrical currents as depicted in figure 1.1 occur in continuous closed paths around the currents producing them therefore a conductor carrying electrical current gives rise to a magnetic field that its strength is proportional to the current in the conductor and the distance from the conductor.

Field lines are usually used to show the magnetic fields and the strength of the magnetic field is constant along the conductor in closed paths around it. In most cases magnetic fields have a complicated appearance that cannot be calculated and must be measured instead. The unit used to measure the magnetic flux density is called tesla [T].

Based on the earlier definitions magnetic fields can be caused by electrical devices and installation cables. [2] "In certain cases, stray currents can give rise to magnetic fields. In Sweden, since the electricity system often contains four conductors leading to each building, stray currents can result in major problems".[2] "

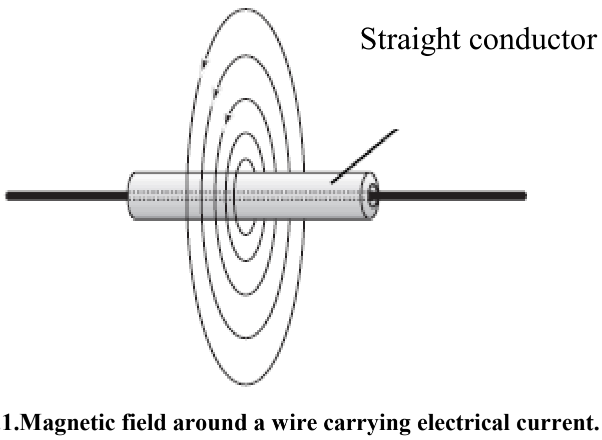


Figure 1.1.Magnetic field around a wire carrying electrical current.

Power lines are also considered as a major external source of magnetic field. The phase current is producing the magnetic field caused by power lines. “Close to power lines magnetic flux can reach to a maximum of 10 to 30 μT but at a distance of 50 to 200 meter it decreases to less than 1 μT” [3].

Magnetic field at homes and working environments are originated from both external and internal sources, typical external sources are power lines, power distribution substations close to residential sections and even water pipes carrying unbalanced neutrals current while internal sources are the households appliances.

As it was mentioned earlier it comes from the definition of the magnetic field that electrical current is capable of producing magnetic field, therefore increasing use of electrical equipments means there is increased exposure to magnetic field. Concerns regarding health hazards due to exposure to low frequency magnetic fields arises therefore International Commission on Non-Ionizing Radiation Protection (ICNIRP) [10] was established to investigate the hazards associated with exposure to non ionizing radiation (NIR) and develop guidelines on NIR exposure. ICNIRP is considering acute health effects that may for example lead to the stimulation of the nerves. Among all guidelines introduced by ICNIRP there are guidelines for limiting time varying electric and magnetic fields (EMF) exposure. ICNIRP guidelines in this regard come in two in two major categories [10].

1. Occupational exposure [10].
2. General public exposure [10].

Occupational guidelines consider the exposure of the workers to time varying electric and magnetic fields at their workplace while general public guidelines consider all people of the society in all ages exposed to time varying electric and magnetic fields even in cases they are not aware of being exposed to magnetic fields [10].
Reference levels for general public exposure and occupational exposure by ICNIRP are summarized in table 1.1 and table 1.2. [10]

Frequency range	magnetic flux density B (T)
1 Hz-8 Hz	$4\times10^{-2}/f^2$
8 Hz-25 Hz	$5\times10^{-3}/f$
25 Hz-50 Hz	2×10^{-4}
50 Hz-400 Hz	2×10^{-4}
400 Hz-3 kHz	$8\times10^{-2}/f$
3 kHz-10 MHz	2.7×10^{-5}

Table 1.1. General public exposure guidelines by ICNIRP [10].

Frequency range	magnetic flux density B (T)
1 Hz-8 Hz	$0.2/f^2$
8 Hz-25 Hz	$2.5\times10^{-2}/f$
25 Hz-300 Hz	1×10^{-3}
300 Hz-3 kHz	$0.3/f$
3 kHz-10 MHz	1×10^{-4}

Table 1.2. Occupational exposure guidelines by ICNIRP[10].

1.2. Health Hazards Associated with Exposure to Low Frequency Magnetic Field

The electromagnetic spectrum includes ionizing, optical and non-ionizing radiation. The non-ionizing radiation is in the frequency range from 0 Hz up to 300 GHz. The energy of the non-ionizing radiation is not strong enough to break the chemical bonds of molecules however there are some biophysical mechanisms that can lead to adverse health effects. For low frequencies the mechanism is stimulation of nerves and cell due to induction of current. For higher frequency ranges the mechanism will be tissue heating [4].

"Extremely low frequency magnetic fields are possibly carcinogenic to humans" [14]. "Epidemiological studies consistently are showing an association between long-term average exposure to magnetic fields above 0.3/04 μT and childhood leukaemia cancer" [4].

In the upcoming section some health hazards related to exposure to low frequency magnetic fields are reviewed based on some major studies.

Power frequency magnetic field is labelled as a possible carcinogen by the International Agency for Research on cancer panel (IARC) [14]. In Japan one of the high exposure areas of the world a population-based case-control study was performed. This study covered areas with 54% of the Japanese children. 312 case children between 0-15 years old with acute leukaemia and 603 controls matched for gender, age and residential area were analyzed. Magnetic field mean was measured in each child house the study showed that most of the leukaemia cases were exposed to magnetic field levels far above 0.4 μT [6].

In another case control study on the relationship between exposure to magnetic field and childhood leukaemia in Ontario, Canada 88 cases comprising incident leukaemia at 0-14 years of age and 133 controls were used. An association between magnetic field exposure and increased risk of leukaemia was observed [5].

In a study performed in San Francisco on the effects of exposure to magnetic field during pregnancy and risk of miscarriage 969 pregnant women all with a positive pregnancy test at less than 10 weeks of gestation and residing in San Francisco were tested. The outcome results were tested using the health maintenance organization databases. No association was observed between miscarriage risk and the average magnetic field level, but it was observed that miscarriage increases with an increasing level of maximum magnetic field exposure with a threshold around 1.6 μT [7].

This all shows it is of great importance to know about the distribution of the magnetic field in the residential areas. The methods used to provide such a graph showing this distribution are explained in the next chapter.

Chapter 2

2. Methods

In the previous chapter the health hazards associated with exposure to low frequency magnetic fields were discussed and based on several studies mentioned in the same chapter. Magnetic fields above a certain level might be considered as a possible threat to dwellers overall health in residential areas, therefore it is of great importance to know about the distribution of magnetic fields in residential areas.

In Sweden Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority) asked Chalmers University of Technology in Gothenburg to perform a study in Gothenburg, Borås and Mark in order to provide the Authorities with magnetic field distribution in the houses of these area.

In this chapter methods for providing such a distribution are described as well as instruments used for measurement purpose. Totally 97 houses in Gothenburg, Borås and Mark in Västergötland were subject of this study. All the houses were chosen randomly to cover all the residential areas in the mentioned areas.

2.1. Instruments

It was explained in the first chapter that magnetic fields tend to have a complicated appearance which usually cannot be calculated, but have to be measured. Five different instruments were used in this stud a short description of each one beside its application in this study is given in this section.

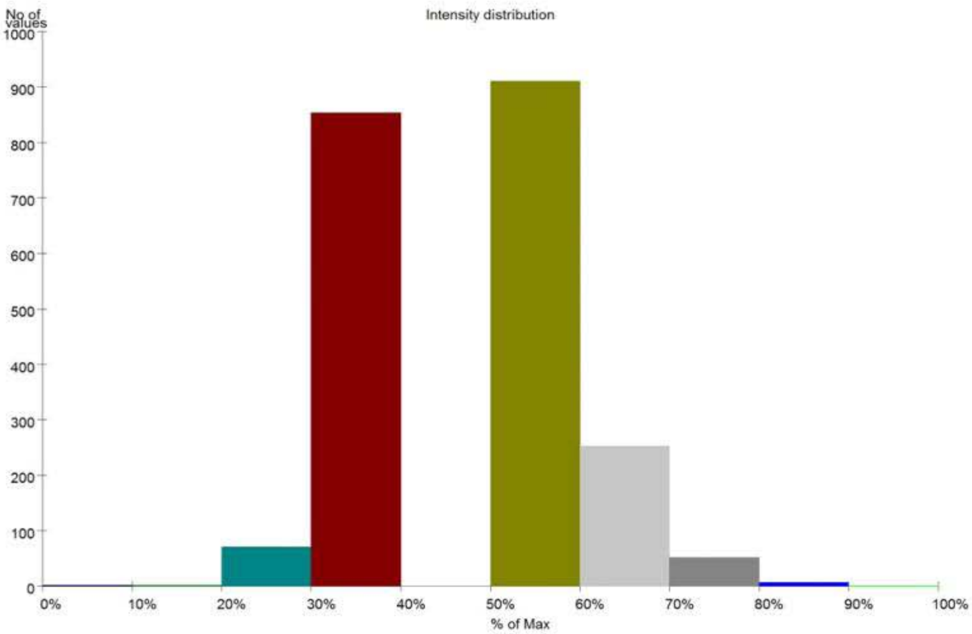
2.1.1. Envirometor ML-1

This instrument is capable of measuring RMS value of the magnetic fields in X, Y and Z direction irrespective of the direction in which the instrument is pointing in relation to the magnetic field. This instrument is able to store the measurement data in a logging basis with logging intervals ranging from 1 second to 150 seconds and totally the instrument can store up to 8,192 readings. The stored data can be transferred to a computer using the Rs232 connection then the PC software accompanying the instrument will provide the user with mean of stored readings

Figure 2.1. Enviromentoir ML-1 magnetic field logger.

Maximum and minimum of stored data, standard deviation, median, high and low quarter [11].

A number of reports and graphs can also be generated using its PC software. Enviromentor Ml-1 frequency range is 30 Hz-2 kHz. In this study we used Enviromentor ML-1 for 24 hours logging in the bedrooms with logging intervals of 40 seconds. However in the houses near the railways this instrument could not be used for 24 hours logging since trains in Sweden are producing a dominant magnetic field at 16.7 Hz and ML-1 due to its internal band pass filter starting at 30 Hz cannot measure this major component therefore due to this hardware limitation for houses near the railways this instrument was not suitable and another instrument Combinova MFM10 was used. In figure 2.2 an example of a report generated by ML-1 PC software is shown.



Started	10/12/2010 5:20:00
No. samples	2153
Interval	40 s
Max	0.08 μT
Min	0.00 μT
Mean	0.04 μT
Median	0.04 μT
Low Quart.	0.03 μT
High Quart.	0.04 μT
Std. dev.	0.00847 μT
File name	C:\Users\abbas\Documents\Thesis\Measurement\Boras Measurment
Comment	

Figure 2.2.Intensity distribution of magnetic field from Enviromentor ML-1

In this report as well as the intensity distribution of the logging data some other statistical information like Min, Max, Mean, Median, Standard deviation, Low quart and High Quart are given.

2.1.2. Combinova MFM10

Figure 2.3. Combinova MFM10 magnetic field logger.

MFM10 is capable of single point measurements of the magnetic field. It can as well be used for logging measurements. The frequency range MFM10 covers is between 5-2000 Hz. Since this frequency range covers the 16 Hz frequency it was used for 24 hours logging of the houses in the vicinity of railways instead of Enviromentor ML-1. The 16.7 Hz magnetic field component generated by trains that is a major component that Enviromentor ML-1 is unable to measure due to its hardware limitations will be taken into account using this instrument. Stored readings From Combinova MFM10 are transferred to computer using RS232 cable as a text file. The logging interval used for MFM10 is 60 seconds. A typical image of this instrument is show in figure 2.3 [13].

2.1.3. MFM 3000

Figure 2.4. Combinova MFM 3000 magnetic field logger

This instrument, as depicted in figure 2.4 is used for single point measurements. MFM 3000 is an advanced instrument that besides giving the total RMS value for the magnetic field it also provides user with the largest and second largest frequency components of the total RMS. The frequency coverage of this instrument is from 5 Hz up to 400 kHz. However this instrument gives the user the possibility to narrow this frequency range. In the case of this study frequencies up to 10 Hz were filtered to reduce the magnetic fields induced into the earth magnetic field due to shaking of the instrument in the earth magnetic field at low frequencies [12].

2.2. Calibration

Before performing any measurements all the instruments used in this study were calibrated. A calibration test was performed in Strålsäkerhetsmyndigheten's laboratory to see if they were all fully functional and measure true values for the magnetic field. For this purpose a set up including a Helmholtz coil producing magnetic field was used The magnetic field created in the centre of coil was calculated then all the instruments were placed in the centre of the coil to see if they were measuring the expected value or not. This set up includes five main parts

1. Signal generator (SPN) (1Hz -1.3MHz) 336.3019.02/SSI 575
2. Amplifier (gain 16.1 for load of 5 ohm) SSI IJ41
3. Resistor to measure the current (3.3 ohm, 1 ohm) SSI IJ26
4. Helmholtz coil (dimension of the box is 56x79)
5. Voltmeter HP3458A SSI IJ30

These five parts were connected based on the scheme depicted in figure 2.5.

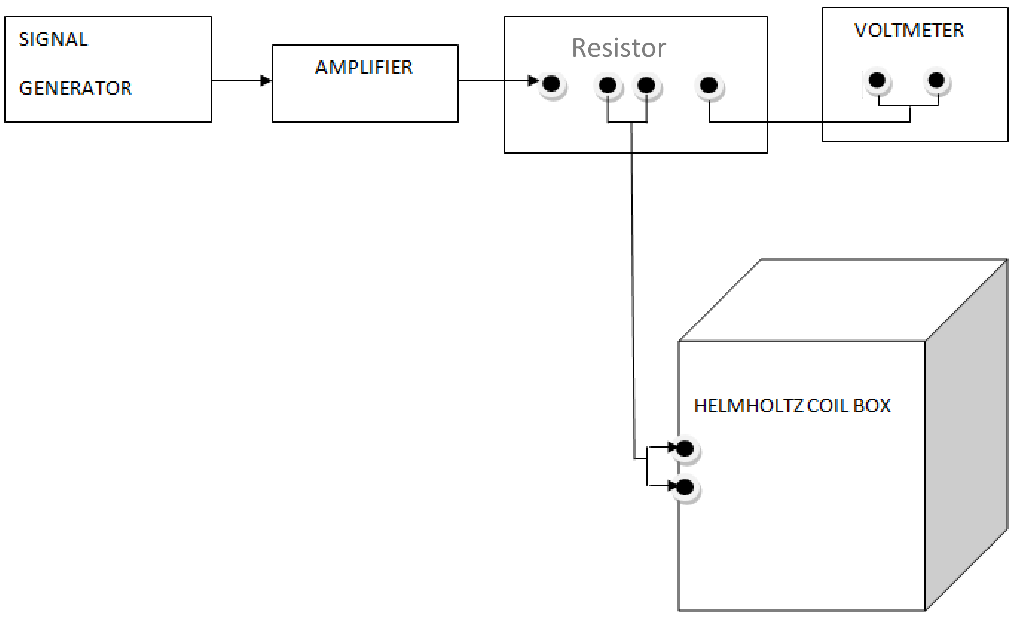


Figure 2.5. Calibration Setup

Signal generator was connected to the Amplifier and then to the resistance. Finally the coil was connected to the other parts.

Equation 2.1 was used to calculate the magnetic field produced by the coil at its centre; therefore the voltage was set to 0.581883 V then based on equation 2.1 all the instruments were supposed to measure a magnetic field of 1 µT (RMS) at the centre of the coil.

$$B = \frac{1.703\ V}{1\ \Omega}\ \mu T \qquad (2.1)$$

2.3. Measurement Metrics

It was mentioned earlier that the purpose of this study is mainly to have the distribution of the magnetic field in houses in Gothenburg, Borås and Mark and a total number of 97 houses were randomly chosen for this goal and a number of metrics have been defined to be express the measurement results from each of these house. In this part a short description of each of these metrics is given then procedures for data acquisition are given in the following section.

2.3.1. Adjusted Average

Two types of measurements are performed in this study one is single point measurement and the other one is the 24 hours logging. For single point measurements Combinova MFM 3000 is used and the single point measurements are performed in the living room, kitchen and bedroom according to the scheme depicted in figure 2.6 in which for each room the magnetic field is measured in the four corners of the room and the center in three different height levels. For 24 hour logging either Enviromentor ML-1 or Combinova MFM10 are used therefore we need a unique formula to calculate the average magnetic field of the house based on the reading of both instruments.

In order to give such a formula two concepts are taken into consideration, first one is the average exposure of the people in house that requires a weighted average formula based on the average time people spend in each room, second is the average magnetic field of the house that is a normal average calculated from equation 2.2. The formula for calculating the average magnetic field that people in each house are exposed to is called B_{adjust} and it is calculated from equation 2.3, 24 or 2.5 depending on the number of houses measured in the house. It is assumed that people on average spend 9 hours in the bedroom 2 hours in the kitchen and 4 hours in the living room.

B_{bed} = 24 h average from the measurement point at the bed.

B_{sleepR} = Room average for sleeping room.

$B_{kitchen}$ = Room average for kitchen

$B_{livingR}$ = Room average for living room

$$\text{Flat}_{\text{Average}}: \frac{Bbed(BsleepR+Bkitchen+BlivingR)}{3BsleepR} \qquad (2.2)$$

$$\text{3 rooms:} \quad B_{adjust} = \frac{\text{Bbed(9 BsleepR+2 Bkitchen+4BlivingR)}}{\text{15BsleepR}} \qquad (2.3)$$

$$\text{2 rooms:} \quad B_{adjust} = \frac{\text{Bbed(13BsleepR+2Bkitchen)}}{\text{15 BsleepR}} \qquad (2.4)$$

$$\text{1 room:} \quad \text{Badjust} = B_{bed}. \qquad (2.5)$$

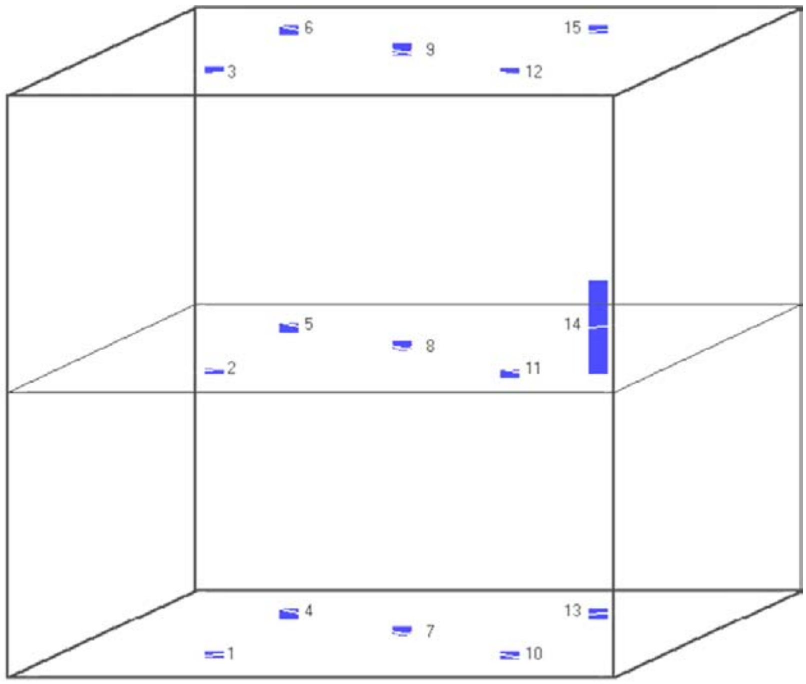


Figure 2.6.Single point measurements scheme.

2.3.2. Total Harmonic Distortion (THD)

In an input-output system if the system is none linear some components will be added to the input and THD is a measure of these extra components added. In this study THD is a measure of the influence of the loads in each house on the current and as a result magnetic field produced by this current. A high value for THD means more none linear loads in the house while a low THD means more resistive loads.

"When the input is a pure sine wave, the measurement is most commonly the ratio of the sum of the powers of all higher harmonic frequencies to the power at the first harmonic, or fundamental, frequency" [8]. This is written in equation 2.6.

$$\mathrm{THD} = \frac{P_2 + P_3 + P_4 + \cdots + P_\infty}{P_1} = \frac{\sum_{n=2}^{\infty} P_n}{P_1} \tag{2.6}$$

Which can equivalently be written as

$$\mathrm{THD} = \frac{P_{\mathrm{total}} - P_1}{P_1} \tag{2.7}$$

If the measurements are based on amplitudes (e.g. voltage or current) these values must be converted to powers. For a voltage signal, this ratio can be written as:

$$\mathrm{THD} = \frac{V_2^2 + V_3^2 + V_4^2 + \cdots + V_\infty^2}{V_1^2} \qquad (2.8)$$

Where Vn is the RMS voltage of nth harmonic and n=1 is the fundamental frequency [8].

“Measurements for calculating the THD are made at the output of a device under specified conditions. The THD is usually expressed in percent as distortion factor or in dB as distortion attenuation.”.[8]
In the case of this study magnetic fields are measured using Combinova MFM3000. In figure 2.7 a typical reading from MFM 3000 is showed therefore using equation 2.7 THD can be calculated from Combinova MFM 3000 readings.

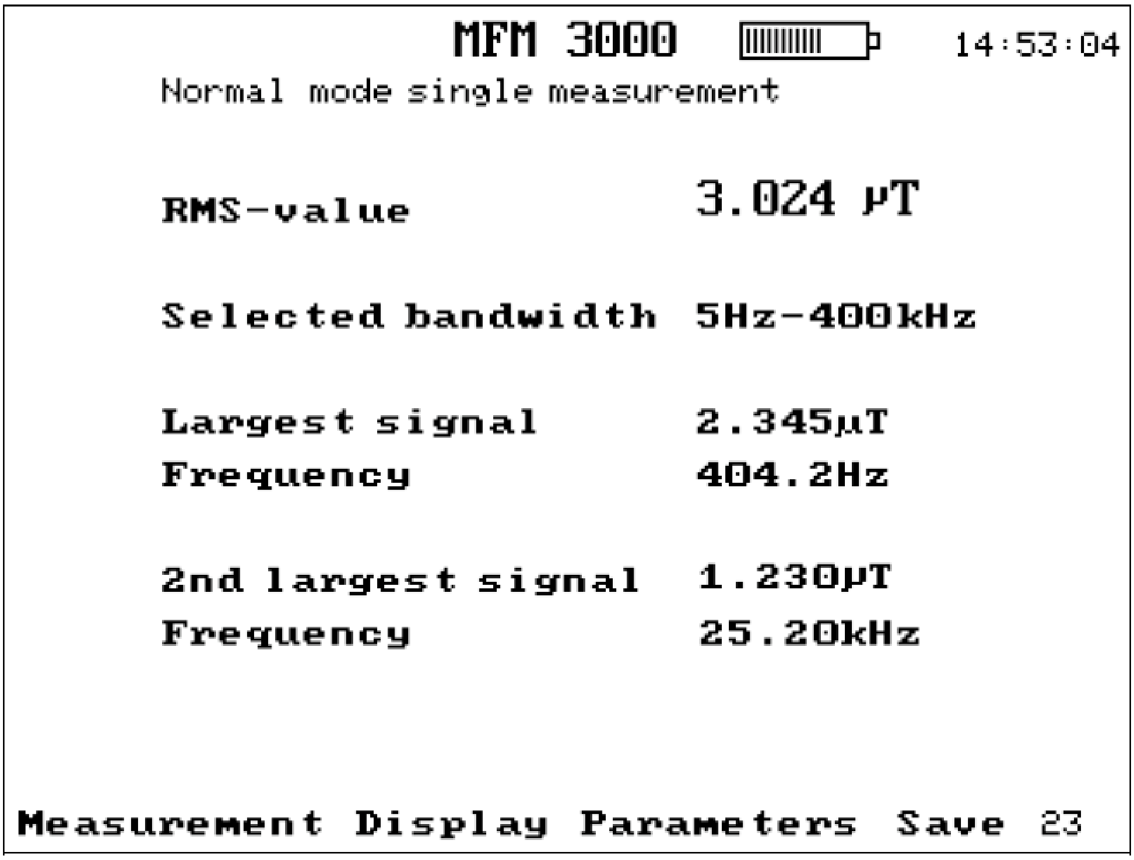


Figure 2.7. A typical measurement on Combinova MFM 3000 display.

Using equation 2.7 P_{total} is proportional to $(B_{RMS})^2$ and P1 is proportional to $(B_{LS})^2$ (square of the amplitude of the largest frequency component) therefore equation 2.7 will change to

$$\mathrm{THD} = \frac{((\mathrm{BRMS})^2 - (\mathrm{BLS})^2)}{(\mathrm{BLS})^2}\ \% \qquad (2.9)$$

At each house there are 15 measurement values in each room and up to 3 rooms (Bed room, living room and kitchen) are measured. The THD for each measurement point (up to 45 values) is calculated and then the average THD is calculated from equation 2.10.

$$\text{THD}_{\text{Average}} = \frac{(\text{THD1} + \text{THD2} + \ldots.\text{THDn})}{n} \quad (2.10)$$

Where THD1 = is the THD for the first measurement point in that house …and THDn is the last measurement point in that house.

Frequency of the 2nd largest signal

For the frequency of the 2nd largest signal the most frequent value for the second largest component frequency from n measurements is chosen. However due to FFT some inexact frequencies can appear, values from 149 to 151 Hz are rounded to 150 Hz and values around 16 – 18 Hz are rounded to 16.7 Hz (train frequency).

However in some cases some conflicts may arise due to measurements uncertainty especially at low amplitudes; therefore some rules are set for calculation of the THD. These rules are listed below.

1. If L.S. > RMS put THD = 0. (If L.S. is considerable > RMS then in data must be wrong, try to correct in data, if data can't be corrected then don't use this data for any calculations (THD and B adjust, levels etc))
2. If L.S. = 0 then do not calculate THD and don't consider it in the average THD.
3. If L.S. is not 50 Hz do not calculate THD and don't consider it in the average THD.
4. If 2nd L.S. is not 0 or 150 Hz do not calculate THD and don't consider it in the average THD.
5. If L.S. < 30 nT do not calculate THD and don't consider it in the average THD.

2.3.3. Fields Highest on Level

The RMS readings for the 3 levels (floor, middle or top) measured in the house are compared therefore there will be up to 15 results per room, for the different positions. In each position the highest field can be at level: floor, middle, top or none (if the measurement values are the same for the two or three highest values). Numbers of highest level at "floor", "middle", "top" or "none" are calculated then the most frequent one is chosen. If the numbers of the most frequent level is shared with more than one level, then "none" is chosen. Since there are two major conventions for floor numbering in the world British and American only one of them should have been used for this study [9]. The floor numbering format used in this study is the British floor numbering an example of it is given below [9].

Displacement from ground level	British convention
3 story heights above ground	"3rd floor"
2 story heights above ground	"2nd floor"
1 story height above ground	"1st floor"
at ground level	"Ground floor"

2.4. Data Acquisition Procedures

2.4.1. Addresses

The addresses used in this study were provided by Professor Lars Barregård, Dept. Occupational and Environmental medicine, Sahlgrenska University Hospital and Sahlgrenska Academy, University of Gothenburg.
The persons had been chosen by random in earlier studies, performed by the Dept. Occupational and Environmental medicine and these addresses were re-used in this study. The addresses were in Göteborg, Borås and Mark. If the persons had moved within the region and we could identify the new address, the new address was used.
The address register contained totally 179 addresses. We were able to get permission to perform measurements at 77 addresses. We were not able to get in contact with 38 addresses, which in most cases depended on that the person had moved without an identifiable new address. We had the person's name and address and not the personal number, therefore new addresses could not be searched for those with common names.

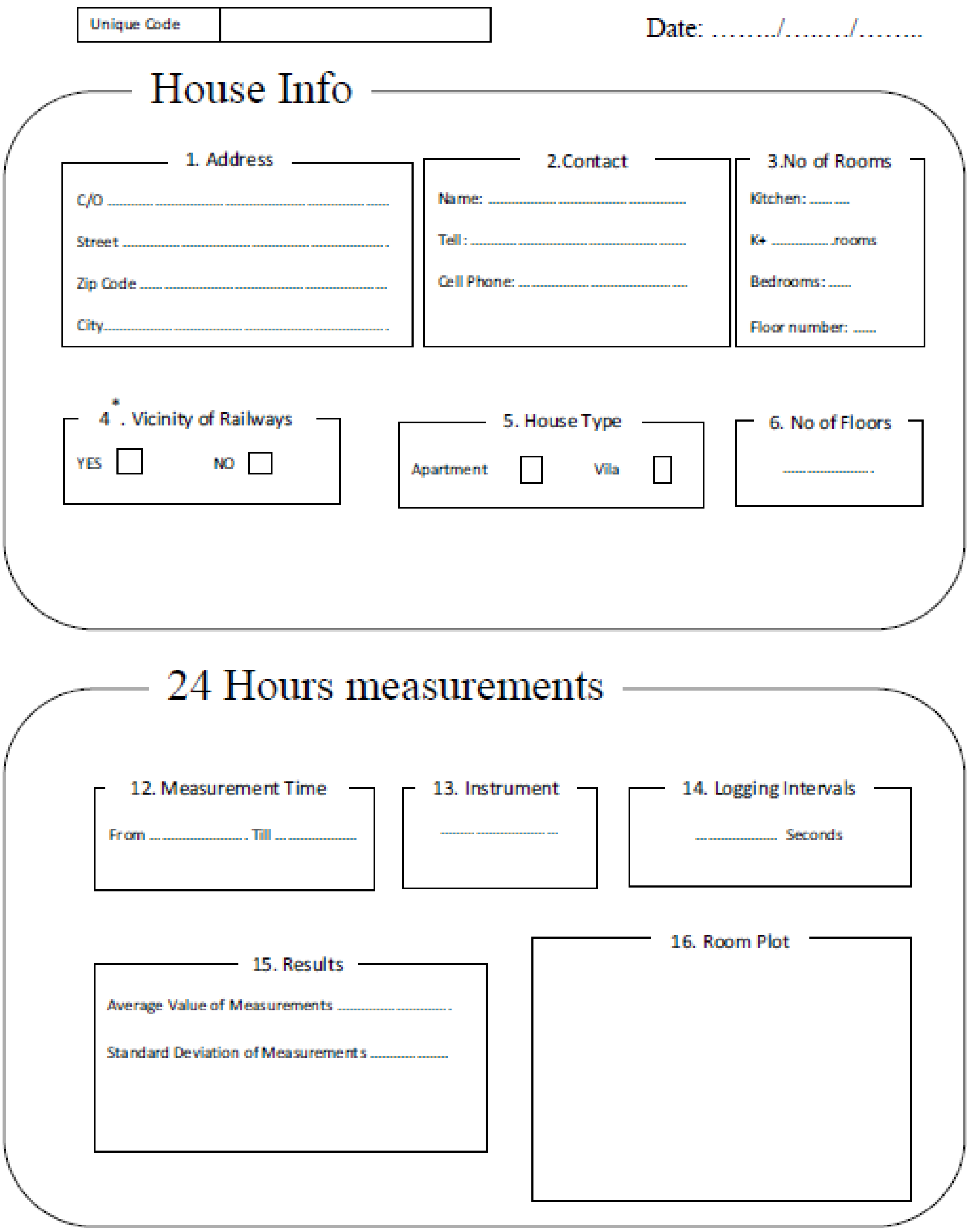
2.4.2. Documentation

All the instruments used in his study are capable of storing readings through their PC software. Beside this computerized method for registering data a check list was used as well for manual documentation of data therefore besides readings from the instruments some additional information regarding each house like house type (if it is a villa or an apartment) and its location (if it is near railways or not) were documented on a hardcopy. An example of this check list for manual documentation of data is shown in figures 2.8 and 2.9.

Beside addresses and contact info a unique code was also assigned to each house therefore the hard copies and softcopies were match easily with an anonymous cod and after sharing the measurement data between group members over internet participants privacy was reserved since there is nothing regarding the identity of the participants over internet and they are all called with a unique dummy cod. For security reasons the method for generation of unique cods is not explained here.

In the first page of this checklist, as it is shown in figure 2.8, basic information like the house type, number of floors and its location if it is near railways or not are filled out then information regarding the 24 hours logging are filled out finally a small plot of the bedroom is given with major magnetic field sources if there is any in the room. In the next pages of the checklist as depicted in figure 2.9 single point measurements from

MFM 3000 are filed out and a simple plot of that room with the major magnetic field sources is included.



Unique Code

Date: ..../......./........

House Info

1. Address
C/O ....
Street ....
Zip Code ....
City..

2.Contact
Name: ....
Tell : ....
Cell Phone: ....

3.No of Rooms
Kitchen: ....
K+ ....rooms
Bedrooms: ......
Floor number: ......

4*. Vicinity of Railways
YES ☐ NO ☐

5. House Type
Apartment ☐ Vila ☐

6. No of Floors
....

24 Hours measurements

12. Measurement Time
From .... Till ....

13. Instrument
....

14. Logging Intervals
.... Seconds

15. Results
Average Value of Measurements ....
Standard Deviation of Measurements ....

16. Room Plot

Figure 2.8. Typical checklist Used in this study.

UNIQUE CODE	TABLE FOR POINT MEASUREMENT: BEDROOM DO NOT FORGET TO SAVE DATA IN THE MFM3000	DATE:

GROUND	A	B	C	D	E
L.S (µT)					
Freq (Hz)					
2^{nd} L.S(µT)					
Freq (Hz)					
RMS (µT)					
MIDDLE 80 cm					
L.S (µT)					
Freq (Hz)					
2^{nd} L.S(µT)					
Freq (Hz)					
RMS (µT)					
TOP 160 cm					
L.S (µT)					
Freq (Hz)					
2^{nd} L.S(µT)					
Freq (Hz)					
RMS (µT)					

Plot over the room:

Figure 2.9. Checklist used for single point measurements.

Chapter 3

3. Results

In the previous chapter methods for measuring the magnetic field were described in details then a number of metrics were introduced to represent the magnetic field measurements corresponding to each house. The final goal of this chapter is to show how many percent of the houses are below a certain value for the magnetic field; meanwhile some individual graphs and values for the measurement metrics introduced in the previous chapter are given.

3.1. Twenty four Hours Measurements Using Combinova ML-1

As it was explained earlier for 24 hours measurements of the magnetic field in the houses not in the vicinity of the railways Enviromentor ML-1 was used in the master bedroom. Here two examples for the distribution of the magnetic field in the bedroom after 24 hours logging are given. Figure 3.1 belongs to a villa house in Borås and figure 3.2 belongs to an apartment in Borås.

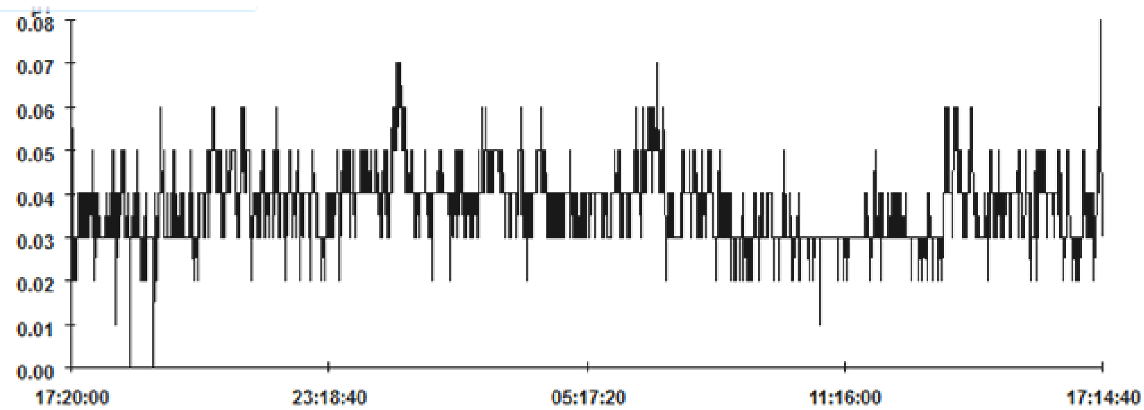


Figure 3.1. Magnetic field distribution of a typical house in Borås after 24 hours logging in the master bedroom.

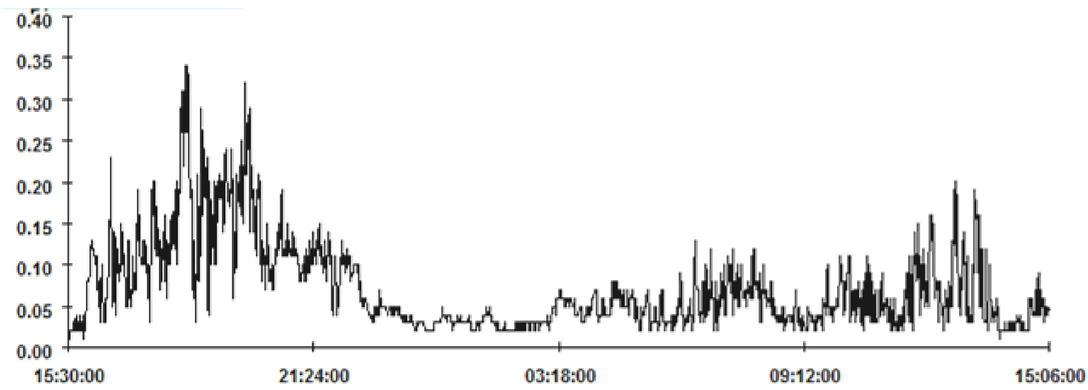


Figure 3.2. Magnetic field distribution of a typical house in Borås after 24 hours logging in the master bedroom.

3.2. Twenty four Hours Measurements Using MFM10

Houses in the vicinity of the railways are exposed to magnetic field at 16.7 Hz since Enviromentor ML-1 rejects the magnetic field components below 30 Hz another instrument Combinova MFM10 for 24 hours measurements in the master bedroom was used. This instrument creates a text file including the logging data, in figure 3.3 part of such a file for a house in Mark is given. The logging interval is set to 60 seconds and the instrument automatically calculates the average value of the logging data for every 30 minutes, however it rejects data that are too far from the range of other data in every 30 minutes.

```
                                                              Average
1   10.11.15  12:09       30        .067     .010 -   .084
              0 %       1415 Hz

        .010      .082      .080      .080      .080
        .079      .084      .082      .064      .063
        .066      .064      .063      .064      .064
        .063      .066      .064      .066      .065
        .066      .066      .066      .063      .066
        .066      .064      .067      .068      .068

2   10.11.15  12:39       30        .065     .061 -   .069   180
              0 %       Mixed

        .068      .069      .069      .064      .064
        .065      .065      .068      .066      .068
        .065      .067      .063      .063      .063
        .061      .063      .066      .067      .066
        .063      .064      .064      .063      .063
        .063      .063      .066      .066      .064

3   10.11.15  13:09       30        .063     .060 -   .071   180
              0 %       Mixed

        .062      .064      .062      .063      .061
        .061      .064      .067      .066      .064
        .064      .065      .063      .065      .064
        .063      .071      .068      .068      .064
        .062      .063      .062      .061      .062
        .061      .060      .062      .062      .062
```

Figure 3.3. Part of a text file from MFM10 containing 24 logging data.

An example of a house near railways having typical low values over 24 hours is given in figure 3.4. This house comprises the average magnetic field of 0.003 μT in the bedroom over 24 hours logging and the adjusted magnetic field average of 0.08 μT from both 24 hours logging in the bedroom and single point measurements in other rooms. THD for this house is 3.6%. In contrast to figure 3.4 an example of a house near railways having high values over 24 hours is presented in figure 3.5. This second house comprises the average value of 0.51 μT for 24 hours logging in the bedroom and 0.39 μT for the adjusted average as explained earlier. THD for this second house is 257.2%. Reviewing these two examples and observing their relevant distribution figures for 24 hours logging in the bedroom reader will have a visual understanding of the difference with the mentioned values.

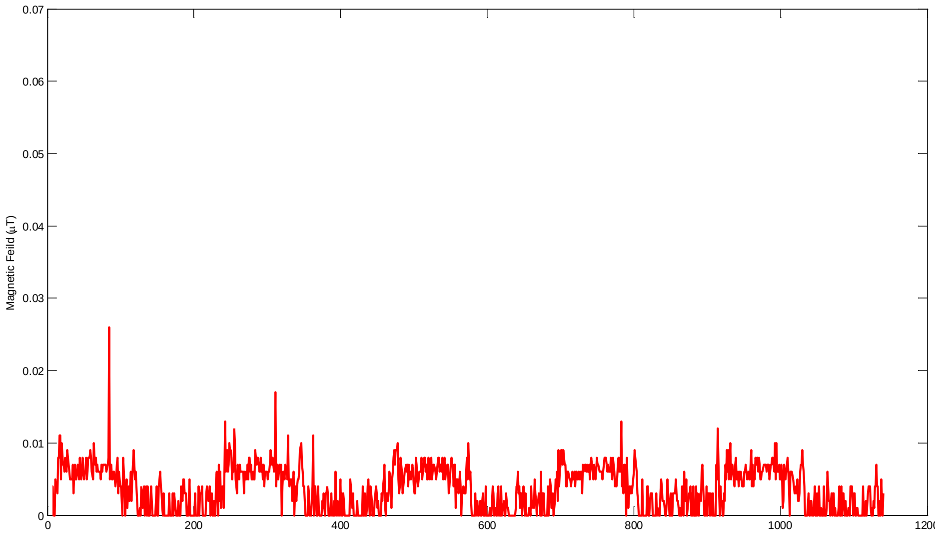


Figure 3.4.A house near railways having typical values for magnetic field over 24 hours logging.

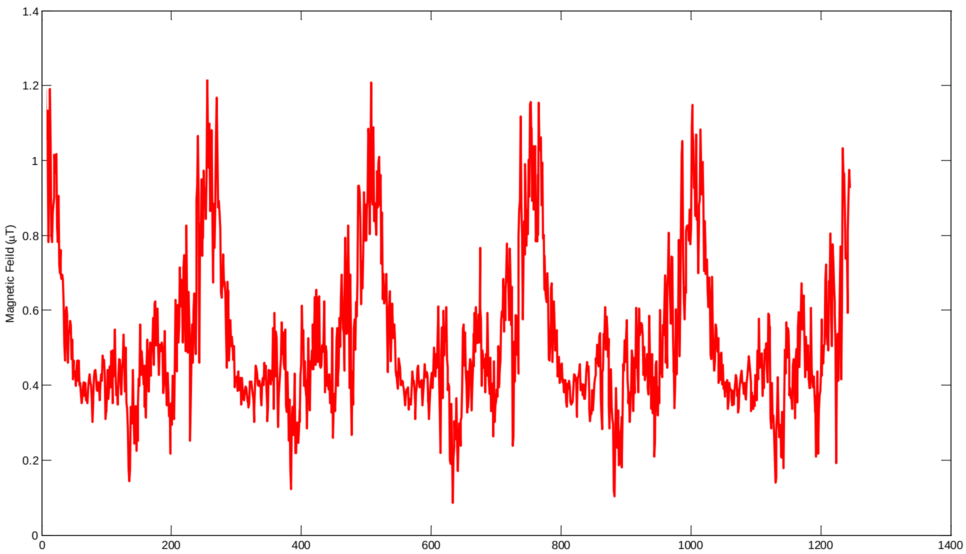


Figure 3.5.A house near railways having high values for magnetic field over 24 hours logging.

3.3. Single Point Measurements Using Combinova MFM 3000

Single point measurements are all performed using Combinova MFM 3000 instrument in 15 different points at three different heights in up to three rooms for each house. Distribution values of magnetic field for all these 45 points are shown in figure 3.6 and figure 3.7 these graphs are coming from the same houses for which the 24 hours logging graph from Enviromentor ML-1 were given in figure 3.1 and 3.2.

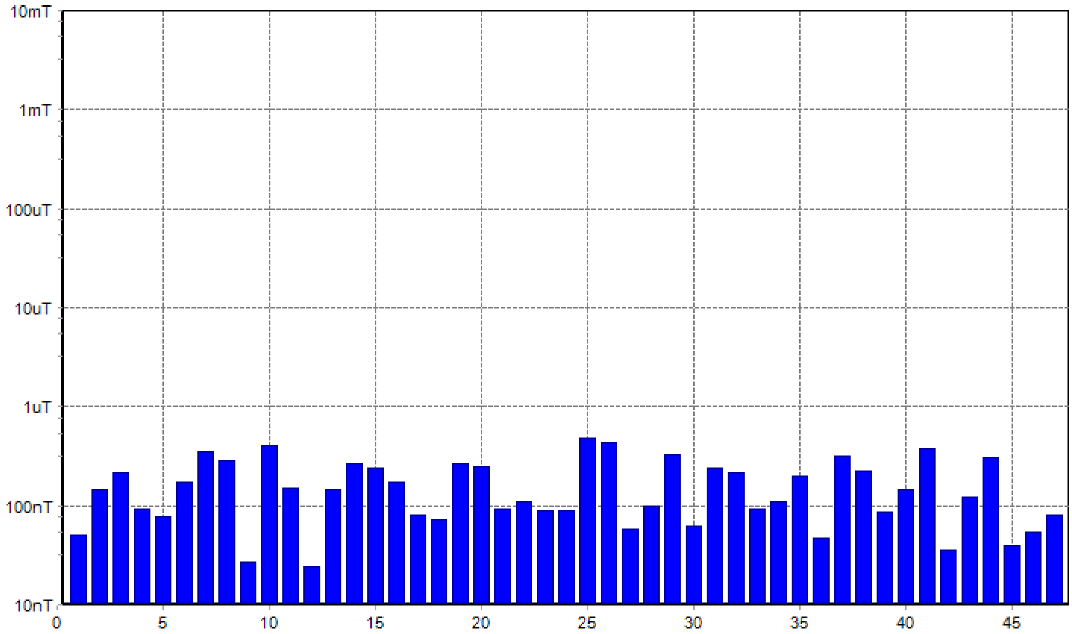


Figure 3.6.Single point measurements for a villa in 45 different single points of living room, kitchen and master bedroom.

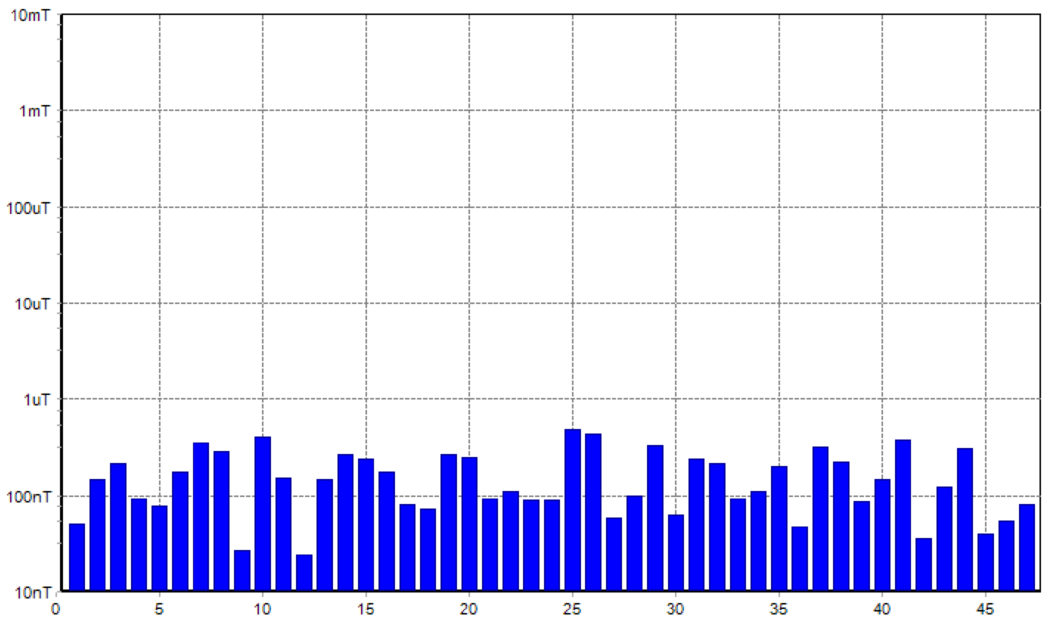


Figure 3.7.Single point measurements for an apartment in 45 different single points of living room, kitchen and master bedroom.

3.4. Final Results

Final results are given in the form of a cumulative distribution function or a bar graph for different measurement metrics defined in chapter 2.

The first section includes a Cumulative Distribution Function (CDF) that shows how many percent of the magnetic field exposure to dwellers calculated from either of equations 2.3, 2.4 or 35 is below a certain magnetic field estimated at the entire house (adjusted average from both 24 hours logging in bedroom and single point measurements in all room). In figure 3.7 this graph is shown.

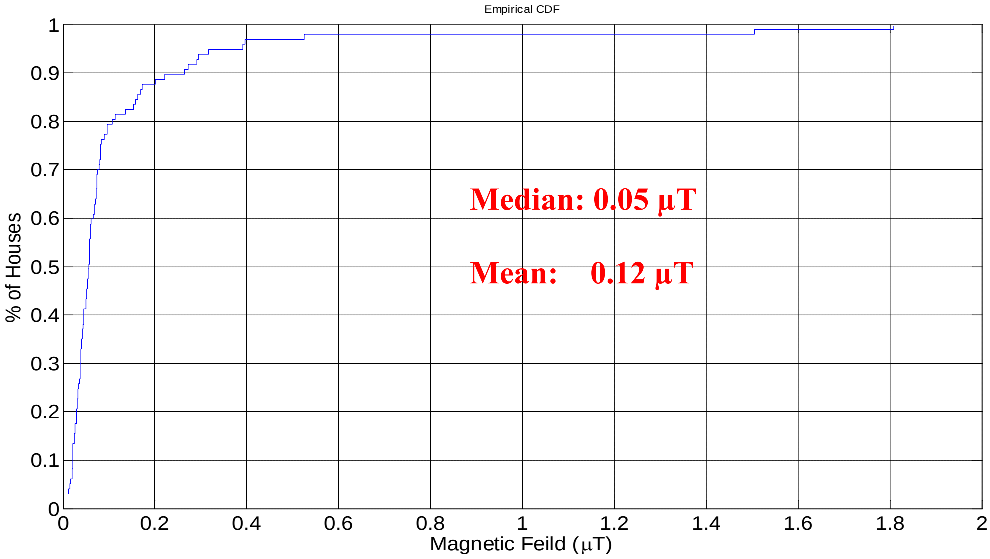


Figure 3.8.Cumulative distribution function showing houses below a certain value for the adjusted magnetic field coming from both single point measurements and 24 hours logging.

This graph shows that 90% of houses expose the adjusted average magnetic field (from both single point measurements and 24 hours logging) in the range 0-0.2 µT to dwellers. This graph also demonstrates that the median of the measurements is 0.05 µT.

In the next graph in figure 3.9 the CDF graph from average value of the magnetic field in the bedroom over 24 hours logging is given.

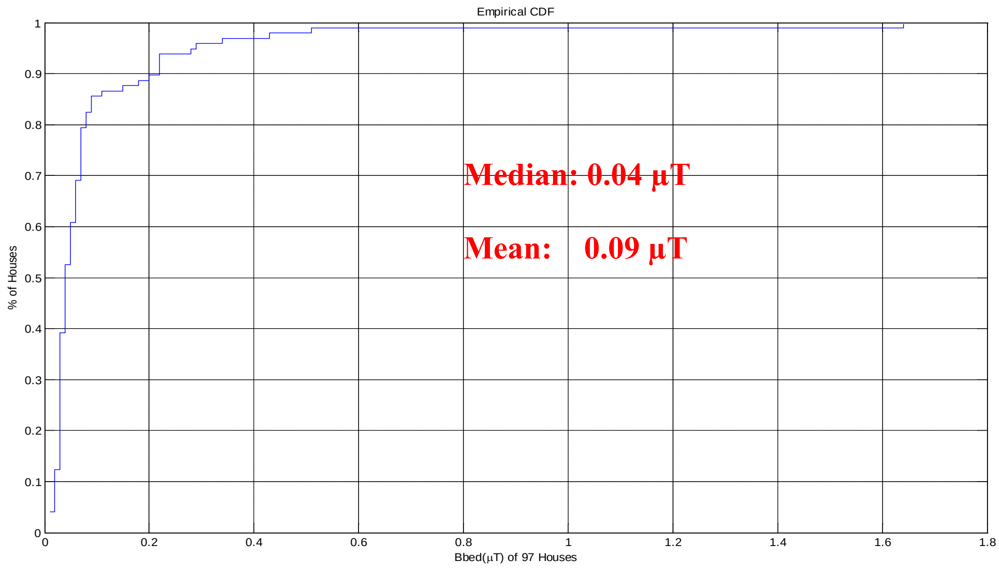


Figure 3.9.Cumulative distribution function showing how much percent of houses are below a certain value for the magnetic field coming only from 24 hours logging in the bedroom

It is evident for this graph that again 90% of the houses have the average magnetic value in the range 0-0.2 μT in the bedroom (this graph comes from the average of the magnetic field in the bedroom after 24 hours logging). Median of these readings is 0.04 μT.

As it was discussed in chapter two regarding the total average value for magnetic field two concepts were taken into account first was the average exposure of the magnetic field to dwellers and second one was the average magnetic field of the flat in figure 3.10 CDF of the magnetic field of houses calculated from equation 2.2 is given. This graph shows that the median value for average magnetic field of houses is 0.05 μT and the mean value is 0.1 μT.

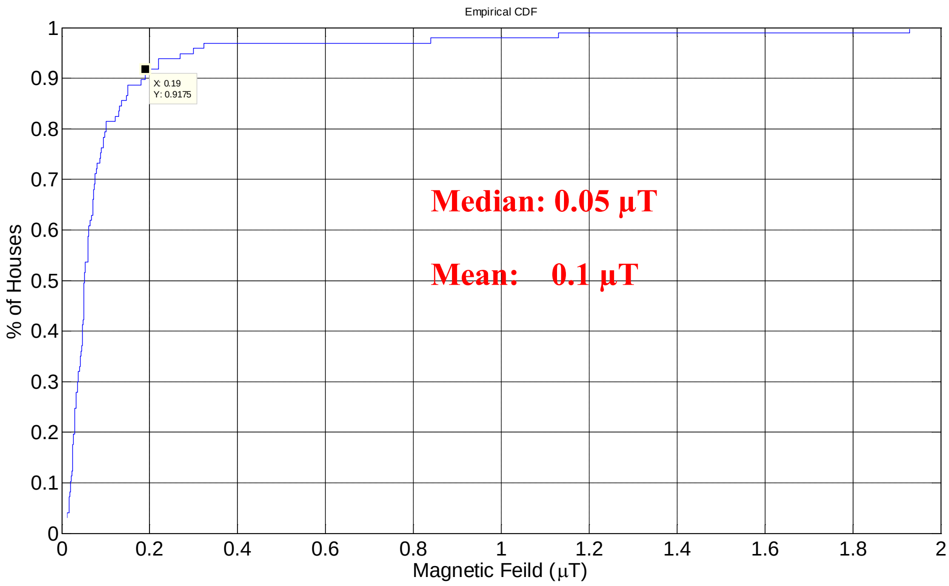


Figure 3.10. CDF graph for flat average magnetic field.

Comparing graphs in figures 3.8 and 3.10 it is observed that the mean value for adjusted magnetic field value (B_{adjust}) exposed to dwellers (0.12 μT) is very close to mean value of the house magnetic field. (0.1 μT). The reason behind this similarity can be due to the similar distribution of the magnetic field in different rooms of a house during 24 hours, therefore magnetic filed in three different rooms of a house during 24 hours have been measured simultaneously with 3 the Enviromentor ML-1. These results are given in the figure 3.11. this figure (3.11) shows that the magnetic field in bedroom, kitchen and living room have similar variations during 24 hours however the distribution of the magnetic field in the kitchen is a bit different from bedroom and living room that is due to existence of many appliances in the kitchen that go on and off automatically. Taking all these facts into account the average exposure of the people is assumed to be the same as the average magnetic field of the house

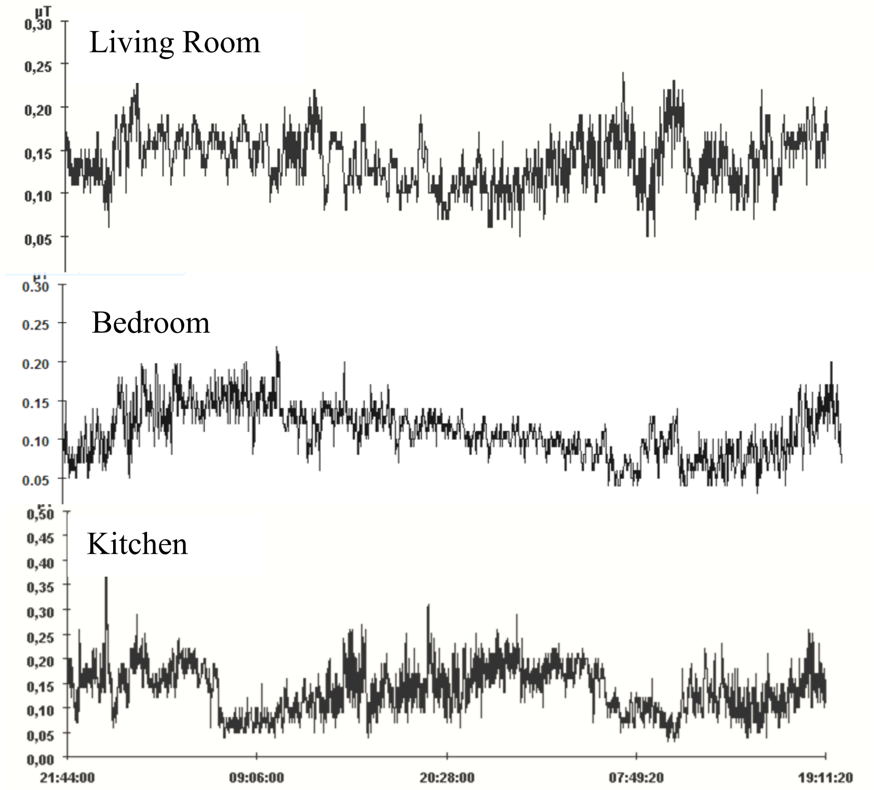


Figure 3.11. Variation of the magnetic field over 24 hours in three different rooms of a house.

In the third section the magnetic field in villas and apartments are compared and CDF of magnetic field for apartments and villas are given in figures 3.12 and 3.13 respectively.

From these graphs we see that the median of the magnetic field in villas is 0.04 µT while the median of the apartments is 0.07µT, also the mean value of the magnetic field for apartments is 0.17 µT and for villas the mean value is 0.09 µT these all show the magnetic field in apartments is greater than the villas which could be due to the influence of neighbour apartments on each other

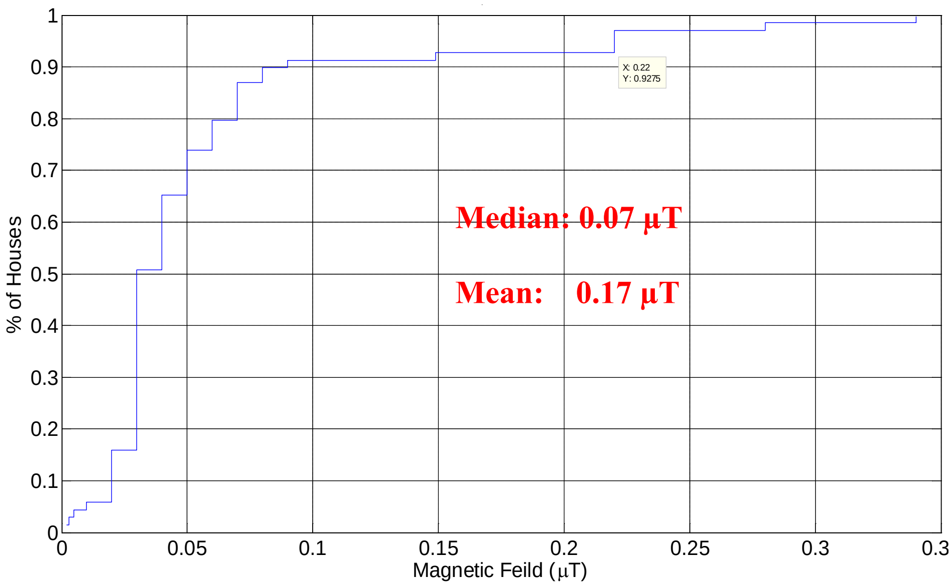


Figure 3.12.CDF of the adjusted magnetic field in apartments.

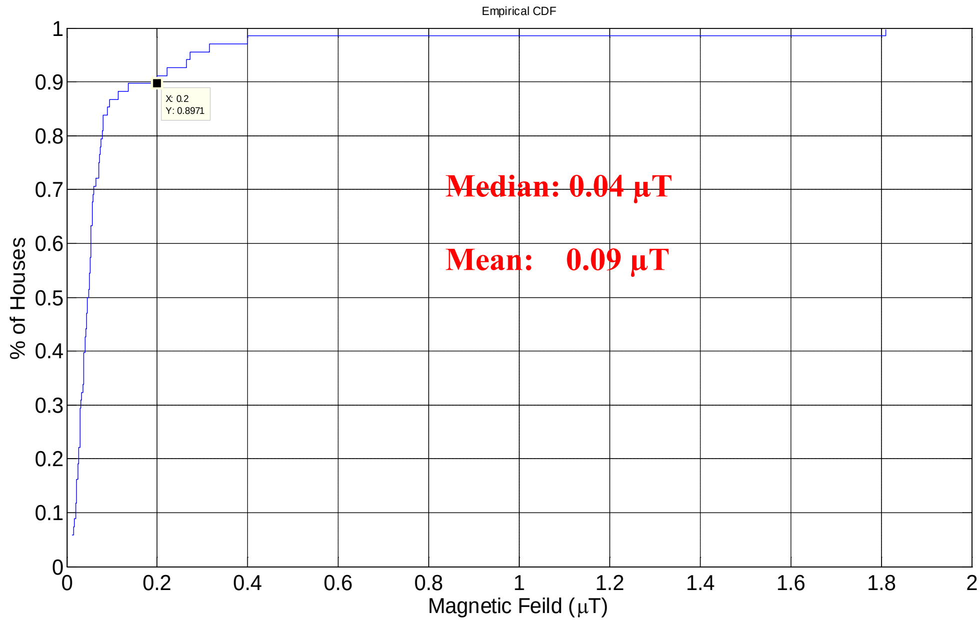


Figure 3.13.CDF of the adjusted magnetic field in villas.

Then a comparison between the magnetic filed in a big city (Gothenburg), small town (Borås) and the country side is held. In figure 3.14 CDF function of the magnetic field in Gothenburg is shown then in figure 3.15 CDF of the magnetic field for Borås is showed and finally in figure 3.16 CDF of the magnetic field for the country side is given.

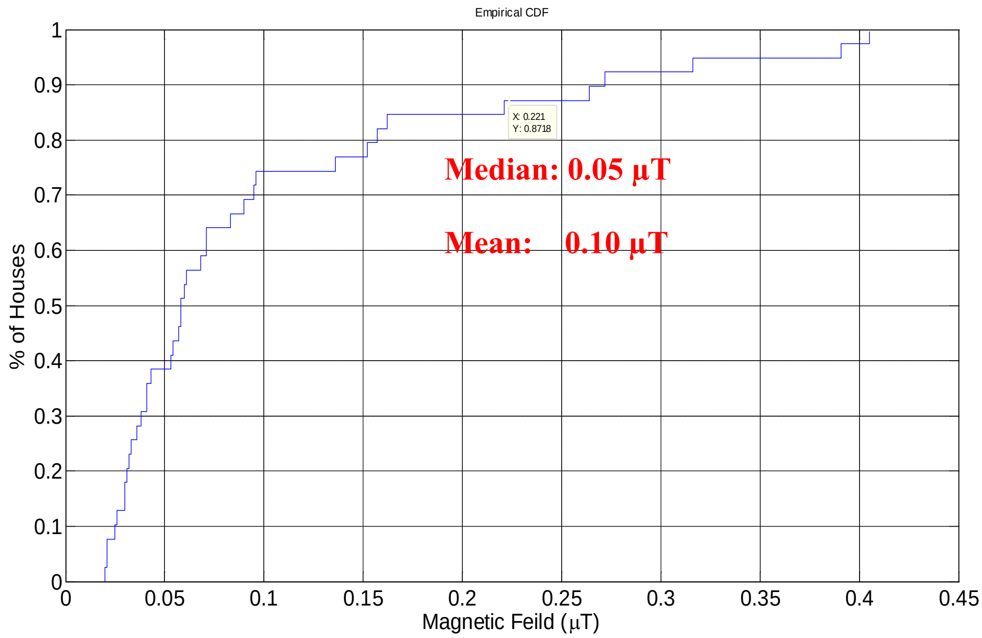


Figure 3.14.CDF of the adjusted magnetic field in Gothenburg.

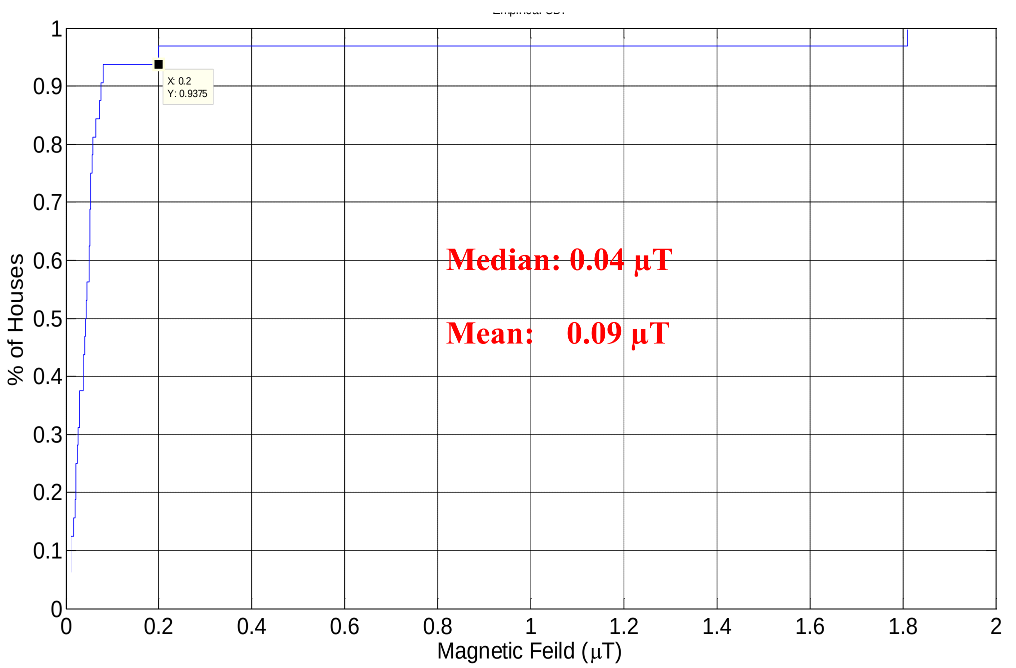


Figure 3.15.CDF of the adjusted magnetic field in the country side.

In table 3.1 summery of these three graphs is given.

Properties	Göteborg	Borås	Others
Percentage of houses < 0.2µT	87 %	85 %	93 %
Median	.05 µT	.07 µT	.04 µT
Mean	0.10 µT	0.15 µT	0.09 µT

Table 3.1. Summery table of the adjusted magnetic field measurements in three different population areas.

This comparison summarized in table 3.1 reveals that the magnetic field in the small town has the highest mean value and the country side (other) has the lowest average magnetic value. We were expecting the country side to have the lows value for magnetic field but our hypothesis was that it is the big city that has the highest magnetic field value one reason for such hypothesis was existence of more apartments than villas and as it was mentioned earlier in figures 3.13 and 3.14 it was seen that apartments has high magnetic field than villas. One reason behind this could be random procedures for choosing addresses.

Next section represents the THD value in a bar graph showing number of houses with a certain THD value. This graph is depicted in figure 3.16.

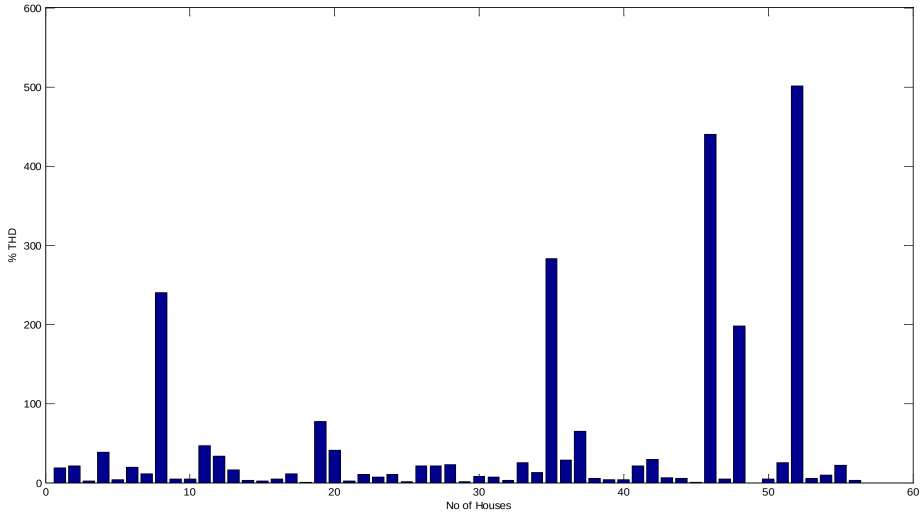


Figure 3.16. Bar graph showing number of houses with a certain magnetic field value

This graph shows that the highest value for THD is 500%. The cumulative distribution function (CDF) for THD is also given in figure 3.17 which also indicates the highest value for THD is 500% This high value for THD shows that most loads at homes are none linear loads. However after doing single point measurements in a number of houses and receiving strange values for THD frequencies up to 10 Hz were filtered because in low frequencies (0-10 Hz) movements due to shakings of the instrument can induce a magnetic field into the earth magnetic field. In order to reject this effect and improve the THD measurement frequencies up to 10 Hz were filtered. In figure 3.11 CDF graph for THD in the houses that this 10 Hz filter was included is given.

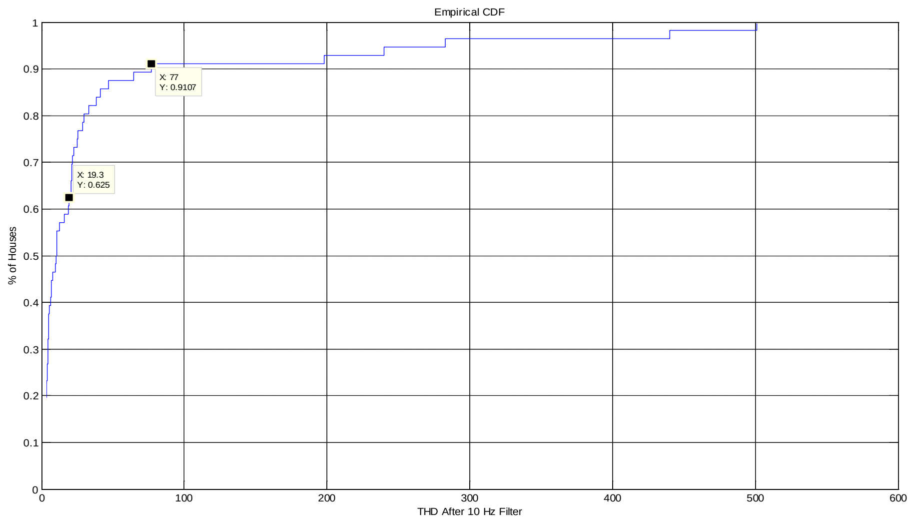


Figure 3.17. CDF for THD

Finally in a bar graph depicted in figure 3.19 it is shown how many percent of the houses have the highest magnetic field in each height level. It comes from this graph that most houses have the highest value for the magnetic field on the floor level this could be due to the wirings under the ground

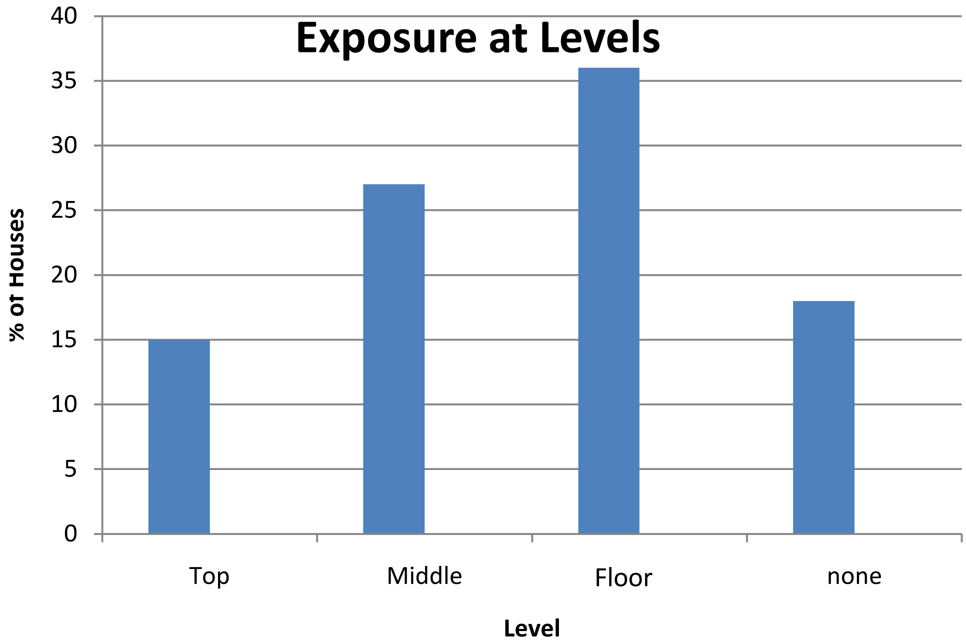


Figure 3.19. Variation of the magnetic field over 24 hours in three different rooms of a house

3.5. Summary Table

In the last part tables contacting all the measurement metrics for all 97 houses are given.

Summary Table

House Unique Code	Average of 24 h logging RMS (μT)	Max of logging RMS (μT)	Min of logging RMS (μT)	Standard deviation of logging (μT)	Adjusted Average RMS (μT)	Flat Average RMS (μT)	THD (%)	Frequency 2nd largest value (Hz)	Fields highest on level (level)	Bed room on floor (floor)	Residence A=Apartment V= Villa (A or V)
B2	0.06	0.15	0.02	0.012	0.073	0.075	320	150	Top	1st	A
B10	0.04	0.14	0.01	0.013	0.045	0.05	18.81	-*	Top	2nd	V
B11	0.03	0.08	0.01	0.006	0.03	0.03	-**	-	Middle	2nd	V
B12	0.07	0.15	0.03	0.018	0.06	0.054	20.9	-	none	1st	A
B13	0.07	0.1	0.05	0.012	0.074	0.074	-	-	Middle	2nd	V
B14	0.07	0.1	0.05	0.012	0.06	0.05	218	-	Top	1st	V
B15	0.07	0.1	0.05	0.012	0.07	0.07	-	-	Middle	2nd	V
B18	0.04	0.27	0.01	0.024	0.04	0.035	10.9	-	Ground	4th	A
B17	1.64	5.45	0.46	0.724	1.505	1.13	240	150	none	1st	A
B19	0.02	0.02	0.01	0.004	0.3	0.038	4.16	-	Top	1st	A
B20	0.05	0.24	0.03	0.03	0.078	0.094	4.33	-	Middle	1st	V
B23	0.03	0.8	0.01	0.018	0.037	0.047	46.8	-	Ground	1st	V
B24	0.07	0.34	0.01	0.053	0.107	0.147	33.16	150	Ground	2nd	A
B25r	0.149	0.24	0.05	0.016	0.113	0.095	16.1	-	Top	1st	V
B26	0.22	0.25	0.07	0.01	0.2	0.19	-	-	none	2nd	V
B27	0.04	0.07	0.02	0.007	0.4	0.84	3.16	-	Ground	1st	V
B30	0.03	0.07	0.01	0.002	0.057	0.076	2.44	-	Ground	1st	V
B31	0.08	0.22	0.02	0.028	0.073	0.071	4.57	-	Ground	2nd	A
B32	0.05	0.27	0.01	0.048	0.048	0.047	372	-	Top	2nd	V
B34r	0.29	1	0.05	0.194	0.525	0.073	10.8	150	Ground	1st	A
B35	0.03	0.06	0	0.005	0.081	0.15	0.428	-	none	1st	V
B36r	0.05	0.21	0.017	0.021	0.057	0.06	77	150	Ground	1st	V
B37r	0.22	0.25	0.01	0.011	0.168	0.136	41.1	-	Ground	1st	A
B39r	0.07	0.19	0.07	0.028	0.082	0.088	1.77	-	Ground	2nd	A
B40	0.02	0.04	0.01	0.003	0.015	0.012	10.6	-	Top	1st	V
B41r	0.05	0.12	0.05	0.014	0.054	0.061	6.83	-	Ground	3rd	V
B42	0.03	0.1	0.01	0.009	0.035	0.047	10.05	-	Ground	1st	V
B44	0.06	0.2	0.01	0.025	0.075	0.086	1.15	-	Ground	1st	V

Table 3.2. Summery table of final results.

*Instrument cannot decide on a certain frequency value.
**10 Hz filter has not been applied, therefore THD is not calculated.

House Unique Code	Average of 24 h logging RMS (µT)	Max of logging RMS (µT)	Min of logging RMS (µT)	Standard deviation of logging (µT)	Adjusted Average RMS (µT)	Flat Average RMS (µT)	THD (%)	Frequency 2nd largest value (Hz)	Fields highest on level (level)	Bed room on floor (floor)	Residence A=Apartment V= Villa (A or V)
B48	0.04	0.07	0.02	0.007	0.04	0.04	21.07	-	Ground	1st	V
B5	0.04	0.08	0	0.008	0.038	0.038	-	-	Top	1st	V
B52	0.03	2.23	0.01	0.044	0.03	0.03	20.9	-	none	1st	V
B53	0.02	0.06	0.01	0.006	0.025	0.032	22.6	-	none	2nd	V
B54	0.00008	0.02	0	0.0009	7E-05	7E-05	1.53	-	Ground	1st	V
B57	0.03	0.06	0.01	0.005	0.044	0.05	7.9	-	Middle	1st	V
B58r	0.22	0.25	0.01	0.011	0.011	0.023	6.85	-	none	1st	V
B59r	0.003	0.07	0	0.003	0.08	0.19	3.62	-	Top	1st	V
B6	0.04	0.12	0.02	0.013	0.046	0.05	19.3	-	Middle	2nd	V
B60	0.03	0.08	0	0.007	0.073	0.13	2.34	-	Top	1st	V
B61r	0.02	0.064	0	0.011	0.037	0.048	38.57	150	Ground	2nd	V
B7	0.07	0.1	0.05	0.012	0.065	0.061	-	150	Top	2nd	V
B8	0.07	0.1	0.05	0.012	0.082	0.098	-	150	Middle	1st	A
G10	0.07	0.24	0.03	0.035	0.068	0.067	64.48	150	Middle	10th	A
G11	0.03	0.07	0.01	0.005	0.032	0.033	-	-	Middle	2nd	V
G12	0.07	0.17	0.03	0.018	0.071	0.072	272	150	Middle	3rd	V
G13	0.03	0.08	0.02	0.006	0.033	0.035	-	-	Ground	4th	A
G14	0.05	0.18	0.02	0.017	0.061	0.07	2.38	150	Ground	7th	A
G15	0.43	1.07	0.09	0.172	0.405	0.22	21.7	150	none	1st	A
G17	0.06	0.21	0.02	0.038	0.053	0.046	-	-	Middle	2nd	V
G18	0.04	0.11	0.02	0.01	0.041	0.042	-	150	Middle	2nd	V
G2	0.04	0.1	0.01	0.011	0.057	0.052	363	150	Middle	2nd	V
G20	0.05	0.08	0.03	0.005	0.036	0.027	-	-	Middle	3rd	A
G21	0.04	0.14	0.02	0.018	0.041	0.043	-	150	Top	4th	A
G22	0.18	0.34	0.06	0.052	0.162	0.15	97	50	Ground	1st	A
G24	0.04	0.07	0.01	0.007	0.043	0.047	-	-	Top	2nd	V
G25	0.06	0.24	0.02	0.026	0.058	0.05	141	-	Middle	2nd	A
G26	0.06	0.13	0	0.027	0.058	0.05	54.8	150	Middle	3rd	A
G27	0.28	0.33	0.16	0.016	0.264	0.27	-	-	Ground	1st	V
G29	0.03	0.08	0.01	0.005	0.272	0.024	-	-	none	2nd	V
G3	0.04	0.12	0.02	0.013	0.06	0.08	-	150	Middle	1st	A
G30	0.02	0.07	0	0.005	0.017	0.016	-	-	Top	1st	V
G31	0.03	0.07	0.01	0.002	0.031	0.032	9.475	-	Middle	3rd	V
G32	0.03	0.07	0.01	0.002	0.026	0.025	-	-	Middle	1st	V
G33	0.2	0.8	0.04	0.114	0.157	0.121	26.86	150	Ground	3rd	A
G34	0.04	0.12	0.02	0.011	0.136	0.064	2.6	-	Ground	3rd	V

Table 3.2. Summery table of final results.

House	Average of 24 h logging	Max of logging	Min of logging	Standard deviation of logging	Adjusted Average	Flat Average	THD	Frequency 2nd largest value	Fields highest on level	Bed room on floor	Residence A=Apartment V= Villa
Unique Code	RMS (µT)	RMS (µT)	RMS (µT)	(µT)	RMS (µT)	RMS (µT)	(%)	(Hz)	(level)	(floor)	(A or V)
G35	0.03	0.07	0.01	0.003	0.03	0.027	87.95	-	none	1st	V
G36	0.03	0.14	0	0.007	0.03	0.018	-	99	Middle	3rd	A
G37	0.03	0.09	0.01	0.005	0.021	0.016	6.513	-	Ground	2nd	V
G38	0.09	0.21	0.03	0.033	0.096	0.101	25.3	150	none	2nd	A
G39	0.09	0.4	0.02	0.045	0.09	0.101	12.8	150	Ground	2nd	V
G4	0.06	0.13	0.01	0.024	0.083	0.078	283	-	Middle	5th	A
G40	0.34	0.54	0.16	0.055	0.316	0.3	28.6	150	Middle	1st	V
G41	0.11	0.39	0.02	0.07	0.152	0.18	64.49	150	Ground	2nd	A
G42	0.08	0.4	0.08	0.057	0.095	0.131	4.654	-	Ground	1st	V
G43	0.03	0.1	0.01	0.005	0.038	0.053	5.076	-	Middle	1st	V
G44	0.51	1.21	0.08	0.203	0.391	0.323	257.2	15	Ground	1st	A
G46	0.22	0.31	0.1	0.057	0.221	0.22	0.771	-	Ground	1st	V
G49	0.02	0.08	0	0.005	0.02	0.02	3.795	-	Top	2nd	V
G50	0.03	0.07	0.01	0.002	0.021	0.016	4.07	-	none	2nd	V
G51	0.03	0.08	0.01	0.002	0.025	0.024	21.35	-	Ground	1st	V
G52	0.09	0.68	0.04	0.053	0.071	0.06	29.7	150	none	4th	A
G7	0.03	0.08	0	0.008	0.054	0.09	-	-	Middle	1st	V
M1	0.05	0.19	0	0.031	0.052	0.052	440	150	Ground	2nd	V
M10r	0.005	0.03	0	0.003	0.007	0.008	5.66	-	none	1st	V
M12	0.03	0.07	0.02	0.007	0.05	0.06	4.34	50	Ground	2nd	V
M14	0.03	0.07	0.01	0.002	0.042	0.042	438	-	Ground	1st	V
M15	0.03	0.07	0.01	0.004	0.03	0.03	-	150	none	1st	V
M16	0.06	0.18	0	0.031	0.052	0.03	9.69	-	none	1st	V
M17	0.03	0.19	0.01	0.006	0.03	0.03	114	-	none	1st	V
M18r	0.01	0.25	0.01	0.01	0.01	0.001	21.76	-	Ground	1st	V
M19r	0.08	1.5	0.08	0.136	1.81	1.93	3.057	-	Ground	2nd	V
M2	0.03	0.07	0.02	0.004	0.02	0.02	-	-	Middle	2nd	V
M21	0.02	0.07	0	0.005	0.021	0.022	0	-	none	1st	V
M3	0.02	0.04	0.01	0.004	0.021	0.024	4.84	-	Ground	2nd	V
M7	0.06	0.16	0.01	0.027	0.053	0.05	243	-	Middle	1st	V
M8	0.04	0.13	0.01	0.015	0.05	0.06	-	-	Ground	2nd	V
M9	0.05	0.15	0	0.016	0.058	0.06	198	-	none	1st	V
M4	0.03	0.07	0.01	0.003	0.026	0.025	25.1	-	Top	2nd	V

Table 3.2. Summery table of final results.

Chapter 4

4. Discussion

It is aimed in this chapter to have a discussion over the results of this study. This study shows that 90% of the houses have the magnetic value in the range between 0-0.2 μT which is reasonable according to the studies over the health hazards associated with exposure to low frequency magnetic fields. However this value is not the net magnetic field for the house but it comes from a weighted average showing the average magnetic field exposed to people in the houses based on the average hours people spend in each room. As it was observed in figure 3.11 the magnetic field in bedroom, kitchen and living room have similar variation during 24 hours however the distribution of the magnetic field in the kitchen is a bit different from bedroom and living room that is due to existence of many appliances in the kitchen that go on and off automatically. Taking all these facts into account the average exposure of the people is assumed to be the same as the average magnetic field of the house. Final results show that the average magnetic field of flat calculated from equation 2.2 is 0.1 μT and the average magnetic field exposed to people based on the average hours they spend in each room coming from equation 2.3 is 0.12 μT. These results also confirm our hypothesis that since the distribution of the magnetic filed in different rooms are similar average exposed to people in the house is very close to the average magnetic field of the house.

This study also tried to give some information regarding the harmonics forming the total RMS and it was observed that the largest component is in the 50 Hz that demonstrates the magnetic field in low frequencies is mainly coming from the power system.

At the beginning very high values of total harmonic distortion (THD) were registered, this was a result of instrument movements in the earth magnetic field which induced stray magnetic field from the earth magnetic field. A 10 Hz filter was applied to reject frequencies up to 10 Hz and thus avoiding stray magnetic fields due to movements of the hand held instrument. The THD values measured in houses before the 10 Hz filter were introduced are not reported in table 3.2.

In many houses the THD values are quite high; one reason could be due to many non-linear loads in the houses. Spectrum of the single point measurements could be a useful tool to dig more into details and seek for the reasons of such strange values for THD unfortunately the MFM 3000 did not have this possibility to have the FFT of all single point measurements and it only calculates the FFT of the last measurements but in this study FFT values for last measurement were all zero that can be due to some problems with the instrument.

It was observed as well that in majority of the cases the largest signal in the harmonics is at 50 Hz.

This study shows that magnetic field for apartments is higher than the magnetic field for villas and this can be explained as the influence of neighbour apartments on each other.

Comparison of the magnetic field value between three different population areas (big cities, small town and country side) reveals that small town has higher mean value for the magnetic field comparing to the country side and big city but since there are more apartments in the big cities and this study shows apartments have higher magnetic field comparing to villas the magnetic field in a big city is expected to be higher than a small town. One reason for such difference could be the random procedures for choosing addresses.

References:

1. Wikipedia " http://en.wikipedia.org/wiki/Magnetic_field" 2010-12-02 at 15:35
2. Ml-1 user manual "http://www.enviromentor.se/manualer/ml1en.pdf" page 4
3. MFM 3000 manual page 6
4. Schüz J, Ahlbom A. "Exposure to electromagnetic fields and the risk of childhood leukemia: a review" Journal, Radiation Protection Dosimetry, Vol. 132, No. 2, pp. 202-211, 2008.
5. Lois M. Green, Anthony B. Miller, David A. Agnew, Mark L. Greenberg, Jiehui Li, Paul J. Villeneuve and Robert Tibshirani." Childhood leukemia and personal monitoring of residential exposures to electric and magnetic fields in Ontario, Canada." Journal, Cancer Causes and Control, Vol. 10, No. 3, 10, pp. 233-243, 1999.
6. Kabuto M, Nitta H, Yamamoto S, Yamaguchi N, Akiba S, Honda Y, Hagihara J, Isaka K, Saito T, Ojima T, Nakamura Y, Mizoue T, Ito S, Eboshida A, Yamazaki S, Sokejima S,Kurokawa Y, Kubo O. "Childhood leukemia and magnetic fields in Japan: a case-control study of childhood leukemia and residential power-frequency magnetic fields in Japan." Int J Cancer, Vol. 119, Issue. 3, pp. 643-650, 2006.
7. De-Kun Li, Roxana Odouli, Soora Wi, Teresa Janevic, Ira Golditch, T. Dan Bracken, Russell Senior, Richard Rankin and Richard Iriye. "A population-based prospective cohort study of personal exposure to magnetic fields during pregnancy and the risk of miscarriage." Journal, Epidemiology, Vol. 13, No. 1, pp. 9-20, 2002.
8. THD from "http://en.wikipedia.org/wiki/Total_harmonic_distortion" 2010-11-27 at 20:5
9. Floor numbering "http://en.wikipedia.org/wiki/Storey" 2010-11-27 at 20:20
10. ICNIRP "Guidelines for limiting exposure to time-varying electric and magnetic field (1 Hz TO 100 kHz)" pp. 818-836, 2010. http://www.icnirp.de/documents/LFgdl.pdf
11. Enviromentor ML-1 manual http://www.enviromentor.se/manualer/ml1en.pdf
12. Combinova MFM 3000 Manual http://www.ergonomicsusa.com/pdf/mfm3000brocB-low.pdf
13. Combinova MFM 10 manual http://www.combinova.se/Text/DL/MFM/MFM10/Brochures/m10broch.pdf
14. IARC Monograph on evaluation of carcinogenic risks to humans volume 80,IARC press, 2002, page 318.

Appendix

MATLAB Cod Used for Plotting the CDF Graphs:

```
clc
clear all

num = xlsread ('Data.xls'); % Upload Excel file
B=num(1:92,5) ;             % Pick column 5 from Data.xls file (Adjust
average)
B=sort(B);                  % sort the values in ascending order
Median1 = median(B);        % calculate median
THD = num(1:92,6);          % Pick column 6 from Data.xls file
Max = max(THD);             % calculate the Maximum value from all
values
Min = min  (THD);           % calculate the Minimum value from all
values
Mean = mean(THD);           % calculate the mean value
T = sort(THD);              % sort the values in ascending order

figure
cdfplot(T)                  % CDF plot of THD
ylabel('% of Houses')
xlabel('THD')

RMS = num(1:92,1);          % Pick column 1 from Data.xls file(Bbed)
Max1 = max(RMS);            % calculate the Maximum value from all
values
Min1 = min(RMS);            % calculate the Minimum value from all
values
Mean1 = mean(RMS);          % calculate the mean value
Median = median(RMS);       % calculate the median value
R = sort(RMS);
figure
cdfplot(R)
ylabel('% of Houses')
xlabel('Bbed')

figure
bar(THD)
xlabel('No of Houses')
ylabel('THD')
figure

cdfplot(B)
set(gca,'FontSize',18)
ylabel('% of Houses')
xlabel('Magnetic Feild (\muT)')
```