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Electromagnetic Fields in Offices

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With the increased use of electric and electronic equipment in our offices, our daily exposure to electromagnetic fields has become increasingly complex due to the great variety of the frequency content of the fields. Today focus has shifted from monitors as the dominating sources of electromagnetic fields to other electronic equipment, cabling, nearby substations, power lines and stray currents in buildings. In the last 5 years wireless communication has become common in our offices. These devices use radio frequency waves to communicate and are therefore sources of radio frequency fields in our offices. To a certain degree, they all add to the complicated issue of the extensive field frequencies found in offices. The exposure of office workers is generally considered to be low and not in conflict with the existing guidelines, but if a precaution approach is applied there are a number of measures that can be taken to reduce the electromagnetic fields in offices in order to obtain a good electrical environment.

radio frequency field office workers exposure

1. INTRODUCTION

Since the late 1970s, there have been global, ongoing discussions on whether our daily exposure to electromagnetic fields can have a negative effect on our health [1, 2]. With the computerisation of the 1980s, worries about negative health effects and unnecessary exposure while working with computers, led to unions' demand for reductions around monitors [3, 4]. Most monitors now meet the requirements for reduced fields, so they can hardly be said to contribute to our daily exposure to electric and magnetic fields in the office. Instead, focus has shifted to fields created by other electronic equipment, cabling and offices' proximity to power lines and substations. It is clear that strong electric and magnetic fields have immediate negative effects on people [5]. Now we also have a European Union directive with recommended limit values, but the risk of being exposed at those levels in an office environment is largely non-existent [6]. However, we know very little about how long-term exposure to weak fields affects us. It is suspected that exposure to weak magnetic fields for long periods could also result in certain health risks [2]. This has led to the application of a precautionary principle to magnetic fields by some international authorities [7, 8]. Precautionary policies, though, are very problematic in their applications [9].

Electromagnetic fields with substantially higher frequencies (radio waves) are now being used for wireless communication between both people and devices. We use GSM phones and various locally installed DECT (Digital Enhanced Cordless Telephony) systems for communication. Computers communicate with each other over wireless networks using Bluetooth technology for fast data transfer over short distances between the computer, mouse, keyboard and printer, and between mobile phones and their peripherals. To a certain degree, they all add to the complicated issue of the extensive field frequencies found in offices.

Can we create a good electric environment with the knowledge we have today? The following sections explain what electromagnetic fields are, how they originated and what regulations and

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recommendations currently exist. We also give advice on how to reduce the fields and show how monitors can be affected by magnetic fields and indirectly become workplace problems. We also provide links to other websites for those who wish to study the subject further.

2. ELECTRIC AND MAGNETIC FIELDS IN THE EXTREMELY LOW FREQUENCY (ELF) RANGE

AC electric and magnetic fields in the ELF range occur due to our use of current.

Fields have different qualities depending on how fast they change direction, namely, the field's frequency. The current in our mains has a frequency of 50 Hz (50 cycles/s) in most European countries, which then becomes the dominant frequency for the electric and magnetic fields found in our offices.

Magnetic fields are measured in Tesla (T) or commonly in the subunit microtesla (μT). Electric field strength is measured in volts/meter (V/m).

When you connect a plug to an outlet, an electric field is created around the device. The higher the voltage, the stronger the field that is created.

Magnetic fields occur only when there is current going through the conductor. Higher current results in a stronger magnetic field.

As we nowadays have more and more electronic equipment in offices the signals are no longer pure 50 Hz sinusoidal. We have an increasing content of harmonics and thereby a broader frequency content of the electric and magnetic fields in offices (Figure 1).

Electric and magnetic fields of slightly higher frequencies (kHz range) occur in electric lighting and around computer monitors.

3. MAGNETIC FIELD SOURCES

Magnetic fields in the office can be generated by outdoor sources as well as by fixed installations and point sources in the environment.

3.1. Outdoor Sources

Magnetic fields are not shielded much by walls; external sources can contribute to increased magnetic field levels inside buildings. Power lines are such a source. Buildings that are close to power lines can have increased magnetic field levels. Proximity to railroads can also give increased levels when a train passes. In some countries DC current is used as power supply for trains and in these cases railroads might not contribute to the AC magnetic field level.

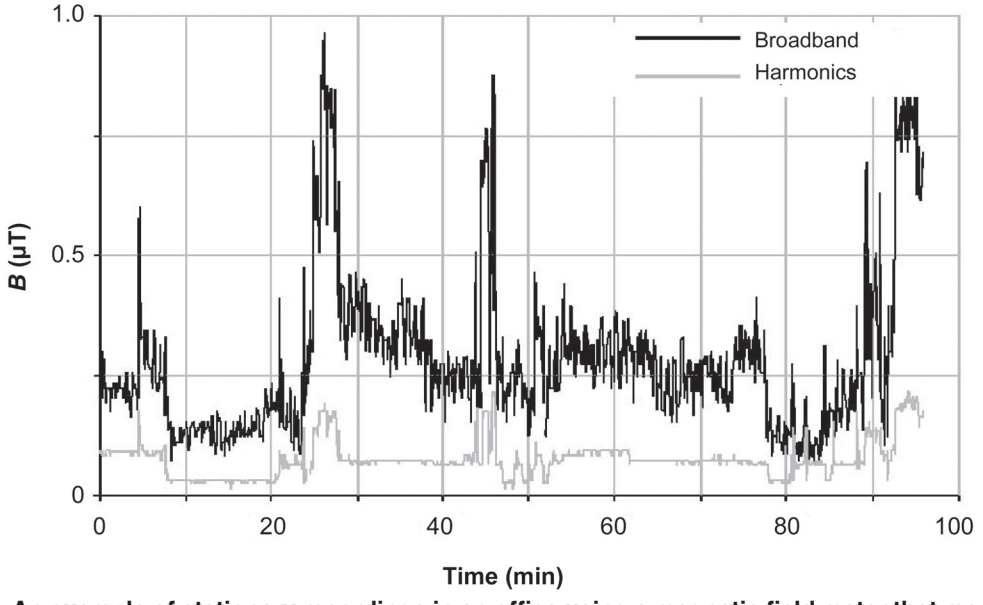

Figure 1. An example of stationary recordings in an office using a magnetic field meter that measures the magnetic field level (*B*) every third second. Both the fundamental and the harmonic signals fluctuate depending on current use at different times.

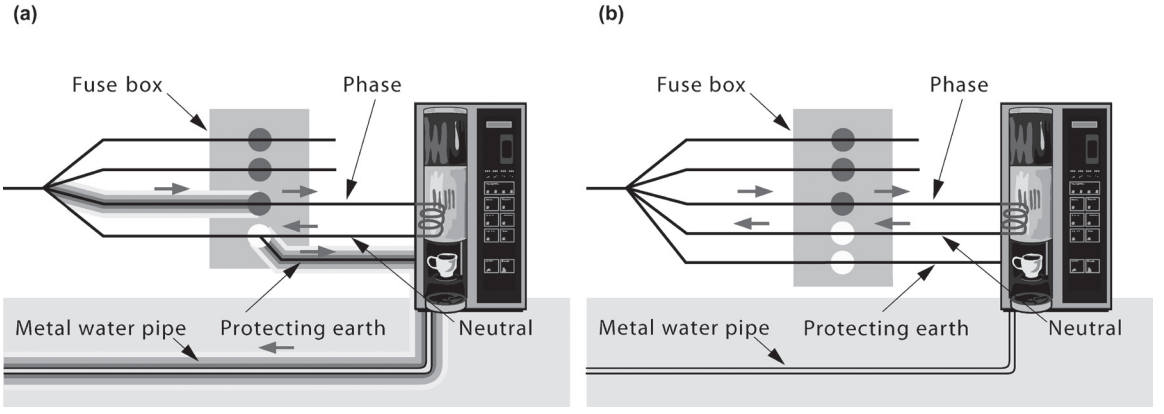

Figure 2. In a 4-conducting system (a) the PE (protecting earth) conductor and the neutral wires are combined (PEN) in the fuse box. In a 5-conducting system (b) the PE conductor and the neutral wires are separated. *Notes*. The shadowed lines around the cables and the water pipe illustrate magnetic fields.

3.2. Fixed Installations

Factors that most often lead to increased magnetic field levels in offices are proximity to in-house substations and distribution boxes, cabling, and most of all, what is usually called stray current. This is current that goes through metal structures such as metal water pipes, district heating systems, cooling systems, and metal reinforcement in buildings instead of the cables that it should be going through, and can thereby cause considerable magnetic field levels in offices and homes. The level of stray current depends on the grounding system an office uses [10]. The most commonly used schemes for grounding low-voltage electrical distribution systems in Europe are illustrated in Figure 2. In a 4-conducting system the PE (protecting earth) conductor and the neutral wires are combined (PEN) in the fuse box; thereby there is a risk of stray current in metal constructions in the building. In a 5-conducting system the PE conductor and the neutral wires are separated, and therefore the risk of stray current is eliminated.

3.3. Point Sources

All electronic equipment in an office also generates magnetic fields of varying degrees. The largest local source is low-voltage transformers that have become increasingly common in equipment such as desk lamps. They emit a locally strong magnetic field, but since it decreases rapidly with distance, they do not contribute much to the general magnetic field level in the room.

Computer monitors are considered to be point sources for magnetic fields where the size of the field depends on which monitor technology is used to create the image (see section 4).

Magnetic field levels in offices

Magnetic field levels in office environments depend on whether they are located in big city environments or in smaller communities. In big cities, power use is generally greater so there is a risk of stronger fields.

There are two ways of measuring magnetic fields in the office. Spot measurements in different points in the room in order to get an estimate of the level [11] or using a portable logger to estimate the office workers' exposure during a working day. The latter method is commonly used in epidemiological studies [12]. Figure 1 shows an example of recordings in an office using a magnetic field meter that measures the magnetic field level every third second.

In general, the average level in an office varies between 0.01 and 0.2 μT if the office is not located near power lines or another external source. Values up to several microtesla can be observed in facilities where stray current is found. If the office is located right above a substation, there can be magnetic field levels of up to 30 μT [13].

4. COMPUTER MONITORS

The degree of electric and magnetic fields around monitors depends on the technology used to produce an image on the screen. Cathode ray tube (CRT) and liquid crystal diode (LCD) monitors are the two most common types. LCD technology, which is also used in laptop computers, has developed rapidly in recent years and is now an economical alternative to CRT monitors.

4.1. CRT Monitors

The image on a CRT is created in the same way as in a TV. Both the CRT monitor and the TV have a picture tube. At the very back of the picture tube there is an electron gun that sends high-speed electron beams through the holes of a perforated plate, which illuminate the red, green, or blue phosphoric layers that are found on the inside of the front of the picture tube. The image on the screen is made up of these small, luminescent dots. In order to display characters anywhere on the screen, the electron beam scans the screen. These movements happen very quickly. A new image is displayed on the screen 70–100 times per second. This is known as the refresh rate and corresponds to a frequency of 70–100 Hz. The left-to-right scanning motion on the screen is even faster, with a corresponding frequency of 30,000–50,000 Hz. These scanning motions are controlled by magnetic coils, which also produce magnetic fields at the same frequencies. In the live parts of the monitor, electric alternating fields are generated with corresponding frequencies as magnetic fields. Both the electric and magnetic fields found around CRT monitors have been successfully reduced to a minimum in the monitors we work with today. However, it is important to remember that the monitor must be grounded for the electric field reduction in modern monitors to have any effect.

4.2. LCD Monitors

An LCD monitor consists of liquid crystals between two glass plates. The image is constructed by using weak electrical signals to turn the crystals and block the light from a certain place. The points that are not blocked produce the image on the screen. Instead of emitting light as CRT monitors do, the LCD monitor reflects or absorbs incident light. The low voltage and current used to create an image also results in low electromagnetic fields around the monitor. Most LCD monitors today use background projection, which produces weak electric fields in the kilohertz range. Even though the technology uses low voltage, it is still important for LCD monitors to be grounded.

4.3. Laptop Computers

The most commonly used technique for laptop computer screens is the LCD technology. These computers run on batteries, but can also be connected to the ordinary power mains via a power supply (charger). When the computer is running on the battery, the field around the monitor is negligible. When the computer is connected to the mains to charge the battery or for a direct connection, magnetic fields of different frequencies are generated around the power supply. These fields decrease rapidly with distance, and there are hardly any elevated magnetic field values in the monitor work area. It is important for the computer to be grounded when connected to the mains. If not, there might be a strong electric field around the monitor.

4.4. Methods for Measuring Fields Emitted by Monitors

Currently, there are two standardised methods for measuring monitor fields: the Swedish Standard No. SS 4361490 and TCO'03 Displays, which is a fourth-generation quality and environmental labelling standard from TCO Development [3, 4, 14]. The TCO standard includes monitors of both the CRT and liquid crystal technology types. Both refer to measurements made in a highly controlled laboratory setting. The Swedish standard reports on measurements of monitors in office environments, but points out the difficulties with such measurements.

TCO labelling, which is used around the world, involves not only the measurement of the electric and magnetic fields found around monitors; it also includes many other criteria in

Figure 3. TCO labelling for video display terminal (VDT) screens, computers, and other office equipment are well known all over the word.

TABLE 1. TCO'03 Requirements on Emission of Electromagnetic Fields From Cathode Ray Tube (CRT) Screens [3]

Type of Field	Max Level	Comments
Electrostatic field	±500 V	
Alternating field 5 Hz–2 kHz		
Magnetic field	0.2 μT	50 cm on all sides and 30 cm in front of the monitor
Electric field	10 V/m	30 cm directly in front of the monitor
Alternating field 2–400 kHz		
Magnetic field	0.025 μT	50 cm on all sides of the monitor
Electric field	1 V/m	50 cm on all sides and 30 cm in front of the monitor

the areas of ergonomics, energy, and ecology (Figure 3) [3, 4].

Table 1 shows maximum levels for the various fields around monitors to fulfil TCO'03 requirements.

4.5. Picture Interference

A poor screen image can be caused by poor technical quality and by settings such as brightness, contrast and colour, but it can also be due to external factors such as incorrect placement of the monitor in the room or high magnetic fields in the room.

In general the image on the screen should be free from disturbing flicker and other forms of instability. Flicker is momentary variations in light that can be visual (we can see it) or invisible (our brains register it but we cannot see it with our eyes) [15]. Working at a flickering monitor can result in eye problems, so it is important to decrease screen flicker as much as possible. Increasing the refresh frequency is one way to do this. TCO'03 recommends a video frequency for CRT monitors of more than 85 Hz.

Another type of interference on the screen is called jitter and can be caused by external magnetic fields.

4.5.1. Jitter

A shaky picture on a CRT screen (jitter) can be caused by a magnetic field in the room (Figure 4). This means that the picture has an extra movement that can be very disturbing to the monitor user [16]. Jitter can occur with different movement patterns depending on the monitor's refresh frequency and the frequency of the magnetic field generated by the source of interference. Studies have shown

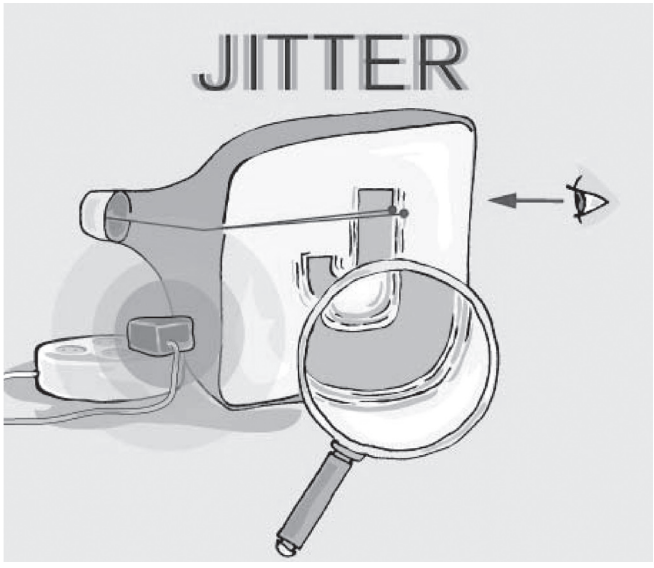

Figure 4. External magnetic field (in this case illustrated by a low-voltage transformer near the monitor) can cause a shaky picture on a cathode ray tube (CRT) screen (jitter).

that magnetic fields of 0.5 μT in a room can cause a visible disturbance on the screen [17]. The interference field can be caused by magnetic fields from electrical appliances that are too close to the monitor, but it can also be caused by outdoor sources such as power lines, stray current at the location, or substations in the building. LCD monitors are not affected by external magnetic fields.

4.5.2. How to avoid jitter

- Avoid placing electrical equipment that generates magnetic fields, such as power supplies, too close to the monitor;
- Try to reduce strong general magnetic field levels in the office (see section 5);
- Switch to an LCD monitor.

5. MAGNETIC FIELD REDUCTION

To reduce the magnetic fields in an office one has to identify the sources. Different sources contribute in different ways. The magnetic fields from point sources decrease rapidly ($1/r^3$) with distance and their contribution to increased magnetic fields is therefore easy to take care of. It is more complicated if there is stray current in the building. Advice for different categories of people is listed here.

5.1. Office Workers

- Turn off equipment you are not using;
- Make sure that low-voltage transformers and chargers are not in your immediate vicinity;
- Make sure power for motorised adjustable desks is switched off when the motor is not in use.

5.2. Buyers of Office Equipment

- Computer equipment and monitors should comply with TCO requirements;
- When purchasing motorised adjustable desks, make sure that power can be switched off when the motor is not in use.

5.3. Building Owners

Elevated magnetic fields due to stray current in the building can be dealt with by changing the electricity distribution system in the building from a 4- to a 5-wire system (Figure 2). This is a costly measure that can only be justified in certain cases. A simpler measure that is increasingly being used is the installation of several booster transformers on incoming power lines [18]. However, for new constructions, it is more suitable to install 5-wire systems.

Offices that are placed directly above an internal substation have elevated magnetic fields; placing

permanent workrooms there should be avoided. If an area above a substation must be used as office space, there is technology currently available for encasing the station [13].

6. ELECTRIC FIELDS

Office buildings effectively shield electric fields that come from nearby power lines and railroads, so these fields very seldom add to electric fields inside offices. The largest contribution comes from ungrounded equipment and cables.

6.1. Fixed Installations

Cabling in a building contributes to the electric field in offices. Elevated levels can also be registered near electrical outlets and switches.

6.2. Point Sources

The biggest source of electric fields in offices is ungrounded equipment. Desk lamps with so-called European symmetric plugs with no ground connection, which are used in some countries, are an example. The way they are plugged into the mains can result in the electric field being even greater when the light is switched off if a simple pole breaker is used and applied to the neutral wire instead of the phase conductor.

A monitor that is not grounded can result in a powerful electric field (see section 4).

7. REDUCTION OF ELECTRIC FIELDS

It is rather easy to reduce the electric field in an office as the field can be shielded. If we shield cables or other equipment that emit electric fields it is of great importance that the shielding is connected to ground. Advice for different categories of people is listed here.

7.1. Office Workers

- Make sure all equipment is grounded;
- Make sure unshielded cables are not close to the metal legs of the desks.

7.2. Buyers of Office Equipment

- Computer equipment and monitors should comply with TCO requirements;
- Only purchase equipment that has ground connections;
- Purchase shielded ducts for cable runs.

7.3. Building Owners

If there is a need for very low background electric fields in an office the following steps might be of interest:

- Use shielded cable for electrical wiring in the building;
- Shield electrical boxes and switches.

8. REGULATIONS FOR ELF ELECTRIC AND MAGNETIC FIELDS

8.1. Limit Values

In many European countries there are currently no limit values for electric and magnetic fields in the ELF range used by ordinary office equipment. However, there is a recent EU directive for occupational exposure that covers all frequency ranges [6]. The authorities in many countries are adapting this directive to limit values, which should be ready within a few years. These directives are based on acute effects-induced current in the body. The EU directive will essentially only affect certain highly exposed groups in industry, such as welders. ELF fields in offices are normally far below the recommended limit values, so it is not an issue in this case. There is also an EU recommendation for the general public [19], but even if these recommended values are 5 times lower than for occupational exposure, the actual values are substantially over the levels we normally see in an office environment [6].

8.2. Precautionary Principle

In the 1990s, several government agencies formulated guidelines for decision-makers on issues dealing with ELF electric and magnetic fields and their possible health risks [7, 8]. Those

guidelines are based on published scientific results, and highlight the technical and economic aspects of the measures that can be taken using limited community resources. As opposed to the limit value discussion on acute effects, this deals with long-term exposure to medium-strength magnetic fields—field levels that can be found in office environments. Some authorities recommend a precautionary principle that is mainly based on a slightly increased cancer risk that cannot be ruled out [2].

As an example the Swedish guidelines [7] are summarized as follows:

> If steps that generally reduce exposure can be taken at a reasonable cost and consistently, you should attempt to reduce fields that deviate strongly from what is considered to be normal in the environment concerned. For new electrical installations and buildings, you should attempt to design and locate them at the planning stages so that exposure is limited (p. 2).

One example is that when new offices are built, the architects should make sure that permanent office workspaces are not placed directly above substations or up against distribution boxes.

9. WIRELESS COMMUNICATION

Over the past decade, wireless systems have invaded offices. Today we work with wireless mice, computers use wireless communication, and phones are wireless. All this signalling is done with radiofrequency (RF) electromagnetic waves. This involves frequencies in the megahertz range (millions of cycles/s) and the transmissions occur with different power outputs depending on how far the signal must travel. This section focuses on systems that are in common use in offices with one exception: regular mobile phones (the GSM and UMTS systems). To read more about these systems and the electromagnetic fields they generate, go to WHO websites [20].

9.1. DECT

The wireless telephony systems that are used in offices are called DECT, which stands for Digital Enhanced Cordless Telephony. Information is sent and received in time intervals. The phone communicates with base stations that are distributed throughout the building, often one per corridor. It is very common today for office buildings, where everyone will use DECT phones, to be built without a fixed hard-wired network. The base stations as well as the phones work at a frequency of 1900 MHz. The maximum output power of the base station and the phone is 0.25 W. The phone transmits only when a call is connected and is otherwise completely passive. If we compare DECT phones with ordinary mobile phones (GSM), the maximum output power of the latter is significantly lower. DECT phones transmit during the entire call, while GSM phones only transmit when you speak and almost never when you are listening. GSM phones can also adjust to lower power outputs if you are near a base station and DECT phones cannot.

9.2. Bluetooth

This technology is used for fast data transfer over short distances (a few metres). It is often used for communication between computers and their peripherals (mouse, keyboard, printer) and between mobile phones and their peripherals (wireless hands-free devices). They often work at 2450 MHz and have a maximum mean output power of 0.001 W.

9.3. WLAN

A WLAN (Wireless Local Area Network) is a locally built wireless network. It is becoming increasingly common for these systems to be installed in offices, schools, and universities. These networks allow wireless communication between computers via a server, but you also have access to the Internet (Figure 5). If you often move around with your computer or change workplaces within a building, a WLAN offers many advantages. You also do not need to pull a network cable where it might cause problems, such as in sensitive buildings or between buildings. WLANs operate at 2450 MHz with an output power of 0.1 W from the antenna. The newer Hiperlan system works at about 5000 MHz and the corresponding output power is 0.2 W.

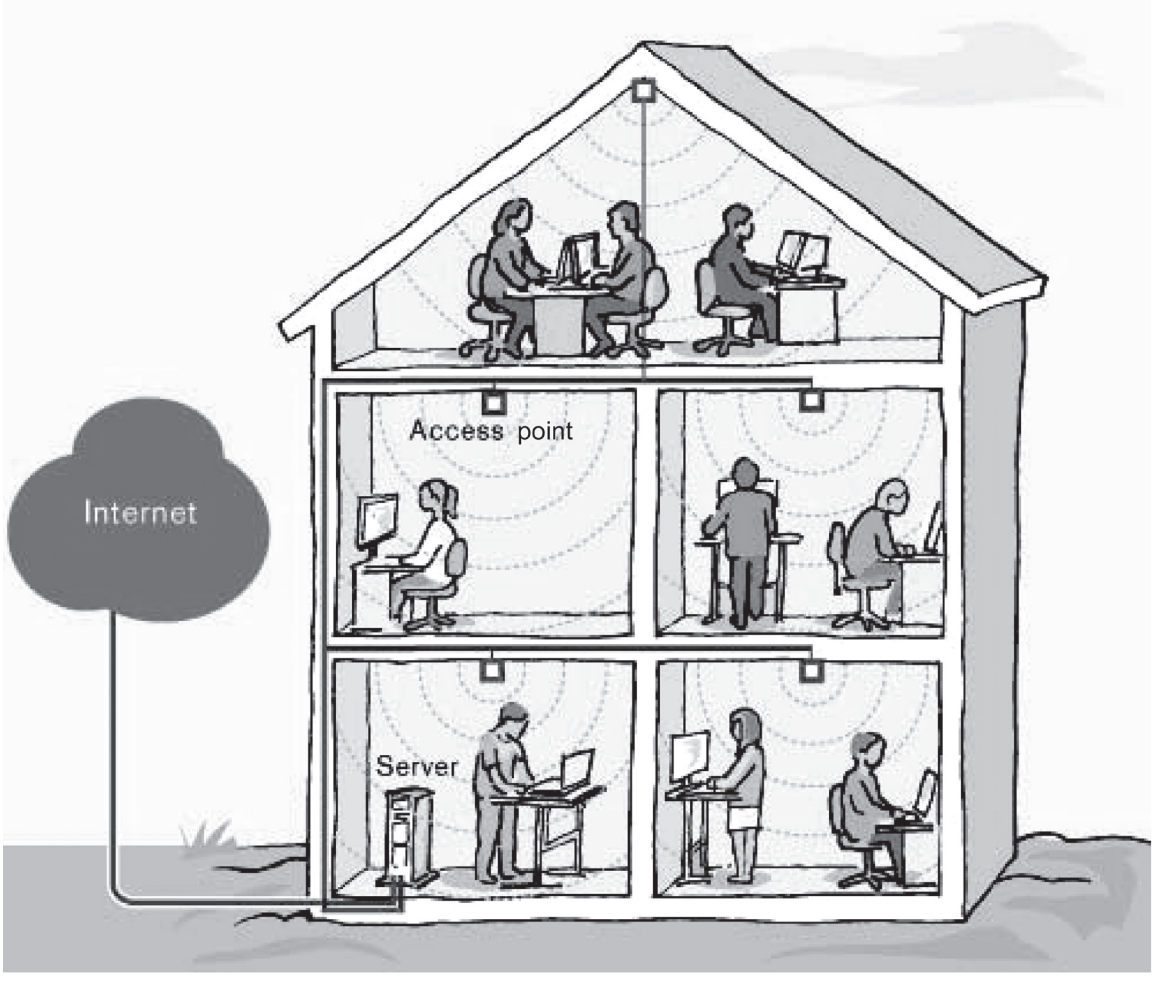

Figure 5. The locally built wireless network (WLAN) allows wireless communication between computers via a server, and also makes access to the Internet possible.

10. REGULATIONS IN THE RF RANGE

The EU directive mentioned earlier covers frequency ranges that include fields from wireless communication in offices. The values in the RF range are based on keeping our bodies from becoming too warm. RF fields penetrate into the tissue to different depths depending on the frequency and the tissue's electrical properties, for example, a few centimetres at the frequencies used by DECT phones. The energy in RF signals is absorbed by the body and generates heat, but the corresponding rise in temperature is limited due to the body's ability to regulate its own temperature. So far, all ascertained health effects are clearly related to heating, and the limit values protect against this. A comparison of the emission proprieties between the different wireless communication systems commonly used in our offices today (DECT, WLAN, Bluetooth) show that this equipment does not exceed the limits recommended by the EU directive [21].

11. SUMMARY

With the use of electronic and wireless equipment the electrical environment in the office and thereby also our exposure to electric and magnetic fields is becoming more complex. To get a full picture of the exposure situation we need to measure the whole frequency range from the static magnetic field up to the radio frequency range. However, in general office workers are classified as a low-exposed group and not in conflict with the

recommendations from the EU. However, if we are discussing a precautionary approach there are a number of measures that can be undertaken in order to reduce the electric and magnetic field.

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