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# Safety and Electromagnetic Compatibility in Wireless Telemedicine Applications

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## 1. Introduction

The vision of our future environment is based on Ambient Intelligence (AmI), being surrounded by various kinds of interfaces, and supported by computing and networking technology providing an intelligent, seamless and non-obtrusive assistance to people. The amount and complexity of health-related information and knowledge has increased to such a degree that a major component of any health organisation is information processing.

The health sector is clearly an information intensive sector, which increasingly depends on information and communication technologies. These technologies are supporting progress in medical research, better management and diffusion of medical knowledge, as well as a shift towards evidence-based medicine. They include tools for health authorities and professionals as well as personalised health systems for patients and citizens. Examples include health information networks, telemedicine services, personal, wearable and portable communication systems and many other information and communication technology-based tools that assist in prevention, diagnosis, treatment, health monitoring, and lifestyle management. When combined with organisational changes and the development of new skills, they can help to deliver better with even a lower cost within citizen-centred health delivery systems.

Mobile technology and wireless solutions promise to transform the healthcare industry. E-pharmacy, asset tracking, mobile voice and media-rich systems are just a few of the solutions that are enabled by those technologies. Wireless communications systems support the aggregation, analysis and storage of clinical data in all its forms; information tools provide access to the latest findings while communication tools enable collaboration among many different organisations and health professionals. Patients and health professionals are becoming increasingly mobile. Both as patients and as healthy citizens, people can benefit from better personal health education and disease prevention. They need support in managing their own diseases, risks – including work-related diseases – and lifestyles. A growing number of people are looking proactively for information on their medical conditions. Personalised systems for monitoring and supporting patients are also currently available – examples include wearable or implanted communication systems to continuously monitor patients' heart conditions. These systems can help shorten or completely avoid a patient's stay at hospital, while still ensuring monitoring of their health status. Health professionals and all the staff employed in the health sector including nursing, care, and administrative staff can also benefit.

Wireless connectivity is becoming increasingly used in Telecare application with intensive use of ubiquitous radio communications such as ZigBee, RFID, UWB (European Commission, 2001). These systems involve sensors, computing and communication devices working in increasingly dense electromagnetic environments. One emerging approach to improving the wearability of continuous ambulatory monitoring systems is to improve body-attached sensors with built-in wireless telemetry, thus freeing the user from having to carry a data recorder. For these telemetry systems, it is likely that a large number of wireless links coexist in the same area sharing the electromagnetic environment.

Nomadic technologies that work in unlicensed frequency bands are turning us into human beings with more and more devices in new electromagnetic conditions not included either in legislation concerning human exposure and the effects of long term, low intensity exposure or with regard to medical devices. Electromagnetic Interference (EMI) can be a serious problem for any electronic device, but working with medical devices can have life-threatening consequences.

Electromagnetic Fields (EMF) are present everywhere in our environment and will continue increasing. In this way, our environment will be surrounded by multiple mobile and stationary devices communicating wirelessly and working together. The level and frequency pattern of that exposure is continuously changing as technological innovation advances. Exposure of the general public and workers cannot be avoided, since various devices emitting low-level EMF are almost omnipresent in the environment, including wearable devices attached to clothes or directly to the body.

## 2. Antecedents / background

Patient-centred care is not new; it has been discussed for over 20 years, but only recently is it beginning to take hold. Increasingly, patients expect physicians to be responsive to their needs and preferences, to provide them with access to their medical information, and to treat them as partners in care decisions. This means that effective healthcare is now happening at the bedside, and not in the Doctor's office, which makes mobility via wireless technology an essential piece of the puzzle. Mobility used to mean doctors, nurses and medical technicians using handwritten notes on individual sheets of paper for transcription into a medical record. In addition to the high cost and delay associated with the manual transcription of patient records, there are non-productive activities such as recording redundant data, searching for misfiled and misplaced charts, and loss of important patient data.

The barriers to effective communications within a healthcare facility are numerous. Large, shift-working populations of clinical, operational and administrative personnel are mobile for much of their day; yet reliable, real-time communications is a vital requirement for them to perform their duties safely and efficiently. In a health care centre every second counts and response time is critical to how well caregivers can meet patients' needs. Multi-media communication systems that integrate wire line and wireless communications, and provide intelligent alerts, telemetry information and even location information can help clinicians evaluate patient needs and deliver appropriate care faster and more efficiently. Complete solutions enable wireless patient monitoring across the entire patient care continuum; from Emergency Care and Anesthesia to Critical Care, Perinatal Care and Home Care.

It is impossible to ignore that the everyday environments for European citizens have been in evolution since wireless technologies (DECT, landline telephones, mobile phones, UMTS,

WiFi, WiMAX, Bluetooth, baby-phones, etc.) have come into widespread use. Recognising the contribution that these new technologies can make, and their omnipresence at work or at home, also implies acceptance of the need for the devices concerned to be assessed before they are put on the market and, more generally, for thresholds to limit the degree of household exposure to RF sources.

Developments in wireless technologies have also had a huge influence in the field of medical applications, enabling wireless bio-monitoring for medical patient care or workers at risk, which can include Electrocardiogram (ECG) temperature, blood pressure, oxygen saturation, internal pressures and respiratory rate. Although the feasibility of using wireless technology to send vital signs was demonstrated more than thirty years ago, it has only been fairly recently that practical and portable devices and communications networks have become generally available. Current development combines some wireless communication technologies (e.g. GSM, Wi-Fi, WPAN, DECT and Bluetooth) to acquire physiological data, monitor patients and manage diseases in a cost-effective manner. Nevertheless, several medical applications use electromagnetic fields in the RF range whose usual frequencies are those allowed for industrial, scientific, and medical applications. There is also potential for new medical applications based on Ultra Wide Band (UWB) communications, for example in cardiology, detection of breast tumours, detection of intracranial haemorrhaging, and the use of sensory implants.

This widespread use of personal communications systems has given rise to much public concern about the possible adverse or dangerous effects of electromagnetic radiation on human health, stemming mainly from the use of mobile telephones and their associated base-station antennas. All populations are now exposed to varying degrees of EM fields. Generally, in the public arena, concern has been often expressed about potential effects of EMF exposure on children's health and on that of older and/or sick people and pregnant women (including the unborn child). This is exemplified by recent public and media concern about potential adverse health effects that might result from the exposure of young people through the rapid expansion of the use of WiFi systems in schools, libraries and universities. Additionally, the population continues to be exposed to the "more traditional sources", like those of radio and TV broadcasting, among others. Some frequencies are now experiencing decreasing usage (e.g. public exposures at 450 MHz from analogue mobile or cordless phones), but others are increasing their usage (e.g. 2.2 GHz from UMTS systems). Scientific evidence on exposure pattern variability related to use of new wireless technologies provides tools for the better understanding of the level of risk related to those technologies, promoting actions required from decision makers to ensure public safety and increasing public trust in the quality of EMF in everyday environments and the work place (WHO, 2005).

There are several previous works of the authors (Ramos, 2005) and also European Cooperation in the field of Scientific and Technical Research - COST - as COST Action BM0704: Emerging EMF Technologies and Health Risk Management (European Commission, 2008). The Action's role, objectives and method of working is entirely harmonious in respect to sharing information and knowledge from relevant ongoing scientific studies being funded within and outside of the EU. These include, for example, the INTERPHONE Study, the mobile phone related dosimetry programme of the Mobile Manufacturers Forum (MMF) and the GSM Association (GSMA) and national programmes of EMF health-related research in EU Member States and elsewhere. The work of the Action is also complementary to the programmes of bodies providing policy-directed advice, such

as the World Health Organization (WHO, 1993), (WHO, 2002), (WHO, 2006). For 10 years, the World Health Organization's EMF Project has been reviewing research needs and identifying key gaps in knowledge requiring further research. Research needs are identified through consensus meetings of internationally recognized experts for the whole EMF frequency range, as is reflected in (WHO, 2010).

### 3. Current state of knowledge and main objectives

#### 3.1 Current state of knowledge

Many devices of common daily use are mobile RF transmitters. One example is mobile phones; about 3 billion people worldwide use mobile phones. The most common mobile communication technologies in Europe are the digital technologies GSM 900, GSM 1800 and UMTS, plus TETRA systems used by public services (police, fire-fighters, etc.). Nowadays, analogue technologies are rarely used in Europe. Mobile phone use is common in Europe and the proportion of users can reach values of 90 % or more. Before mobile phones can be brought into the European market they have to show compliance with the requirements of European Directives, i.e., limits for the amount of power absorbed in the human body has to be shown. Standardised methods specified by the European Committee for Electrical Standardisation (CENELEC) are used to test mobile phones in Europe. The limit for mobile phone use is the specific absorption rate (SAR) of 2 W/kg for the human head – other limits are provided for power exposing other parts of the body.

Mobile phones are tested under standardised conditions, i.e. at the highest power level, e.g., 2 W peak power corresponding to 250 mW maximum time averaged transmitted power for GSM at 900 MHz. Maximum local SAR values averaged over 10 g of tissue range typically between 0.2 and 1.5 W/kg, depending on the type of mobile phone.

In addition to mobile phones, other wireless applications like cordless phones, e.g. DECT, or WLAN systems are very common. Due to the fact that they are usually operated with lower output power compared to mobile phones the exposure is typically below the level of mobile phones. The maximum time average power level of a DECT base station is 250 mW, for a DECT handset is 10 mW. The peak value of a WLAN terminal is 100 mW, however the average power depends on the traffic and is usually considerably lower. The exposure from such systems is therefore typically below that of mobile phones, however under certain circumstances, e.g. closeness to WLAN access points, exposure due to WLAN or DECT systems can become superior compared to the exposure from GSM or UMTS mobile phones. Anti-theft devices have become more and more common during recent years. They are typically used at shop exits or similar areas to prevent theft of goods. Some of the existing systems are operated in the RF range. The exposure depends on the type of system it is. As long as the systems are operated according to the manufacturer's requirements and the systems comply with relevant CENELEC standards, below the exposure limits. RF exposure for workers can be caused by several industrial appliances operating in the RF range, for example for heating (e.g. RF sealers) or from maintenance of broadcasting stations or radar installations. The exposure to the worker operating such systems can reach values close or even above the limits of the Directive 2004/40/EC.

Regarding the objectives of this chapter, two main RF sources are considered: those operated for general purpose far away from the human body, and those generated by medical applications.



*a. Sources operated far away from the human body*

Such sources are typically fixed installed RF transmitters. An example is base stations that are an essential part of mobile communication networks necessary to establish the link between the mobile telephone and the rest of the network. In most European countries, base stations have become ubiquitous in guaranteeing connectivity in large areas of the respective countries.

Other important RF sources are broadcasting systems (AM and FM radio and TV). The range of exposure is similar to analogue TV systems. However, the digital systems require more transmitters than the older analogue systems; therefore there is public concern that this can result in somewhat higher average exposure levels.

Other examples of sources relevant for far field exposure of the general population are civil and military radar systems, private mobile radio systems, or new technologies like WiMAX.

*b. Medical applications*

Several medical applications use electromagnetic fields in the RF range. Therapeutic applications such as soft tissue healing appliances, hyperthermia for cancer treatment, or diathermy expose the patient well above the recommended limit values to achieve the intended biological effects. These include heating of tissue (analgesic applications) or burning cells (to kill cancer cells). Therapeutic and diagnostic applications, like Magnetic Resonance Imaging (MRI), are allowed to exceed the basic restrictions of Council Recommendation 1999/519/EC as there is a benefit for the patient. In these cases exposure of therapists or other medical personnel needs to be controlled to avoid the possibility that their exposure exceeds the exposure limit values stipulated by Directive 2004/40/EC for occupational exposure. Usual frequencies are those allowed for industrial, scientific, and medical applications similar to most industrial sources. Magnetic resonance imaging devices in medical diagnostics use RF fields in addition to static and variable fields. Most actual clinical MRI devices work at 63 MHz or 126 MHz.

Concerns have been fuelled by the introduction of these technologies, often in the absence of a reliable knowledge base, on both likely exposure to people and on potential adverse health effects. This experience has highlighted the need for foresight and pro-action in dealing with the introduction of such technologies. Now, retrospectively, the results of good quality research are being published which provide a measure of reassurance as to the general low levels of exposure and to potential effects on health of some existing EMF technologies, but not for all technologies. The cost of such uncertainties and lack of foresight has been significant in respect to introducing these technologies and to health and other public authorities in dealing effectively with public concerns. In the years ahead, many new EMF related technologies will be introduced and potential health concerns should be identified and addressed through: a rigorous examination of the technologies in respect to their use and exposure to people, identification of potential adverse health effects in the light of current scientific evidence, exchanging the results of ongoing research and, overall, the provision of a focus for information exchange and research activities.

The situation of EM environments in healthcare facilities must be differentiated - where medical devices and human exposure are under control of the healthcare organization- from home and mobile situations, as is the case for a growing number of modern telemedicine applications.

Today, with the aid of telemedicine, patients can remain at home, which provides a better quality of life, especially for the prevention and management of chronic illnesses of elderly people. Telemonitoring and telecare systems are playing a key role in bringing attention to

patients with mobility impairments and that require constant attention but have no doctors nearby. In contrast to the conventional use of medical devices, the latest wireless sensors are wearable and can be used intermittently over a long period of time by a large number of people.

The problem arises when wireless telemonitoring and telecommunication systems coexist in the same environment. The current electromagnetic compatibility and immunity standards do not cater for the emerging home telemonitoring scenarios. The compatibility among the new technologies of wireless communication becomes a critical issue for telemedicine applications, especially when dealing with continuous data, whose readings should not be interrupted, for example in critical cases of ECG monitoring.

### 3.2 Research objectives

This chapter discusses Electromagnetic Interference (EMI) by means of recognition, which involves not only the devices themselves but also the environment in which they are used, and anything that may come into that environment. Several factors make EM compatibility difficult. These include proliferation of new devices, mobility, the trend toward digital interfaces and the reliance on weak signals. Other factors are the unprecedented changes in medicine technologies as well as new wireless-frequencies management, services and technologies.

“Nomadic technologies” that help to free up our everyday lives for example microwave ovens, mobile phones, remote controls, etc. tend to utilize unlicensed frequency bands where the Resulting Electromagnetic Interferences (EMI) can have an effect on any electronic device. The result with a medical device would not only be an inconvenience but also it could potentially be life-threatening. Particularly as these telemetry systems will have to coexist in the same home electromagnetic environment as a large number of other wireless links. In the current standards, there are no quantifiable conditions regarding human exposure and long-term and low-intensity effects and medical devices Electromagnetic Compatibility (EMC).

The necessary effort to assure Electromagnetic Compatibility (EMC) of personal mobile telemedicine is motivated by the possible degradation in electronic medical devices, which could potentially result in deaths, serious injuries, or administration of inappropriate treatment. Furthermore, the electromagnetic environment continues to intensify with cellular and portable phones, wireless modems, mobile communications, paging systems, and telemetry, which share communications frequencies with home medical telemetry devices. Device users are generally not aware of the field strengths, frequency distribution, or temporal characteristics of their electromagnetic environment. The focus will subsequently shift to identify those EMF technology applications and services currently in use and/or likely to be released in the future and, where possible, to characterise likely exposures and identify potential health concerns associated with their use. Likely candidates might include, for example: so-called 4G (and further developments in mobile telephony), ad hoc networks, W-LANS, WiMax, Zigbee, Bluetooth, Wimedia, UWB, broad-band over power transmission lines, various EASD and RFID applications and further digital broadcasting.

One emerging approach to improving the wearability of continuous ambulatory monitoring systems is to improve body-attached sensors with built-in wireless telemetry, thus freeing the user from having to carry a data recorder. For these telemetry systems, it is quite probable that a large number of wireless links coexist in the same area sharing the

electromagnetic environment. There is negligible or relatively little knowledge of local sources of RF radiation on close proximity to metallic implants, external or implanted medical devices.

The focus of this chapter is the characterization of electromagnetic environments currently present in urban homes in order to make an assessment for the potential safe use of home telemonitoring systems, according to the international standards for RF immunity of medical devices set by the International Electrotechnical Commission (IEC) Standard 60601-1-2. There is no regulation yet for the emerging telemedicine home scenarios.

#### 4. Methods

Nowadays the use of RF sources is widespread in our society. Prominent examples are mobile communication, broadcasting or medical and industrial applications. Information on emissions arising from RF sources is often available and can be used for compliance assessment or similar applications such as in-situ measurements. It should be taken into account that information on the exposure of individual persons is scarce. Such information is mainly needed for epidemiological studies. There is therefore a need to optimise methodology to assess individual exposure, e.g. by using and further developing existing dosimeters.

The existing RF sources are operated in different frequency bands and emit different output power (EMF levels). Developments in wireless technologies have also had a huge influence in the field of medical applications, enabling wireless bio-monitoring for medical patient care or workers at risk (Budinger, 2003). Nevertheless, several medical applications use electromagnetic fields in the RF range whose usual frequencies are those allowed for industrial, scientific, and medical applications similar to most industrial sources.

The problem arises when wireless telemonitoring and telecommunication systems coexist in the same environment, as the current electromagnetic compatibility and immunity standards do not cater for the emerging home telemonitoring scenarios. The compatibility among the new technologies of wireless communication becomes a critical issue for healthcare environments (Urdiales-Garcia et al., 2007).

In order to assure the compatibility among wireless systems, EMF measurements have to be performed. To make EMF measurement in the frequency range 100 kHz to 300 GHz, different sets of instruments for each of the frequency spans must be used. Usually the instrumentation only covers a certain range of frequencies, for instance from 100 kHz to 30 MHz, another set goes from 10 MHz to 300 MHz and other from 100 MHz to 10 GHz. For frequencies below 300 MHz typically, both the electric and magnetic fields must be measured. Below 100 MHz there is also a need to measure both the contact and the induced current, and this demands another set of instruments.

Regarding the assessment of Electromagnetic Compatibility (EMC) in healthcare environments, several measurement procedures could be proposed. The first one is calibrated to obtain the EMF trend averages, maxima and minima over time. These values can be achieved measuring the EMF with a wide band dosimeter. In order to analyse the contribution of each emitting source over time, a second procedure based on a selective filtering of the spectrum is proposed. A dosimeter with predefined frequency bands is needed for this purpose. Finally, an ad hoc study could be performed by means of a spectrum analyser, obtaining the fundamental frequency, harmonics and emission power.

Regarding the assessment of Electromagnetic Compatibility (EMC) in healthcare environments, two different measurements have been performed. In order to analyse the



contribution of each emitting source over time, measurements have been performed in urban homes using dosimeters with predefined frequency bands. The second one has been made in the laboratory, by means of measuring the radiation emitted by several RF emitters devices.

#### 4.1 Measurements in urban homes

This research addressed the characterization of EM environments present in urban homes, regarding the assessment for potential safe use of home telemedicine systems. EM field levels have been measured with both ESM-30 “RadMan XT” Radiation Monitor and a portable device ANTENNESSA EME SPY 120, during the years 2007 and 2008. The first one used is a battery powered, portable ESM-30 “RadMan XT” Radiation Monitor (Narda Safety Test Solutions GmbH) that automatically measures and records data on site. This device measures according to the standard ICNIRP-98 in broadband and the E-field and H-field is expressed as percentages of the standard limit values in range 1 MHz - 40 GHz (see Fig.1 and Fig.2).

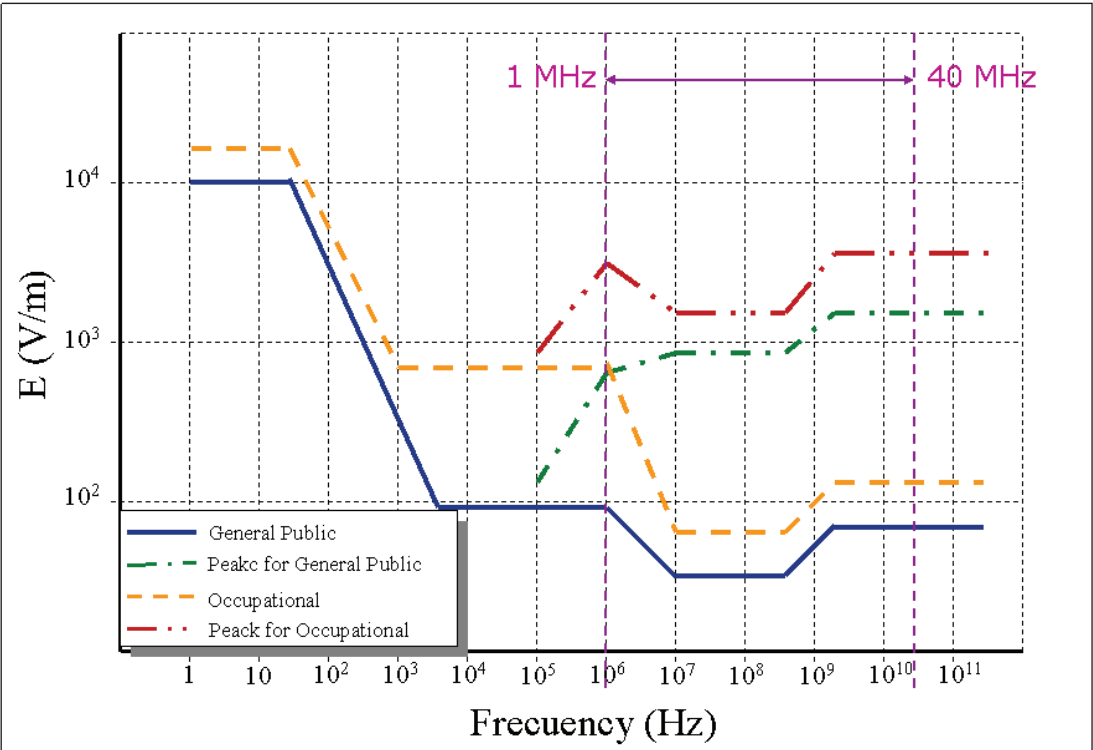
The second dosimeter used is a dosimeter ANTENNESSA EME SPY 120. It is a selective, isotropic personal exposure meter that has been designed for epidemiological studies. It can measure 12 frequency bands (FM, TV3, TETRA, TV4&5, GSM Rx&Tx, DCS Rx&Tx, DECT, UMTS Rx&Tx, Wi-Fi) and can identify the contribution of each emitter. This device measures the E field according to the standard ICNIRP-98 and also gives results in V/m and  $\mu\text{W}/\text{cm}^2$ . It has been configured to sample every 90 or 120 seconds, and the measurement period is 7 to 9 days in 16 hour segments respectively.



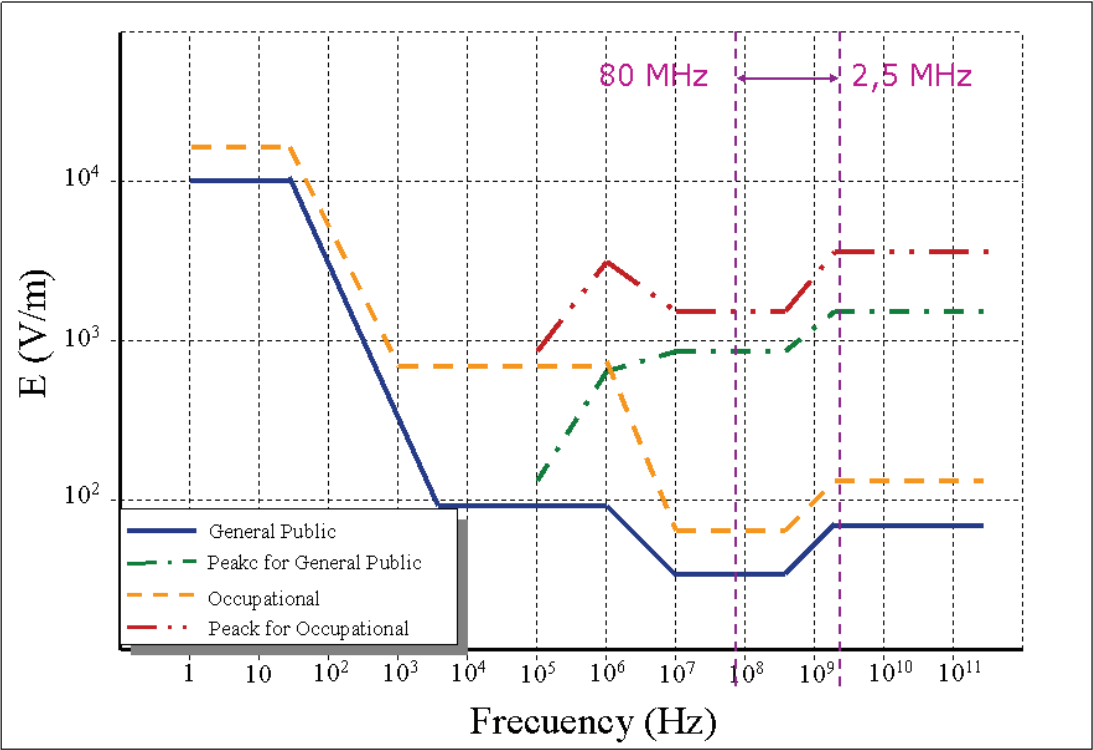
Fig. 1. Antennessa EME SPY and RadMan XT dosimeters

During the measurement time, dosimeters have been placed in different rooms of the houses. The position of the dosimeters in each room is random, although if there is any electronic device, it was recommended to place the dosimeters between 50 cm and 1 meter, in order to keep far field condition.

Data from these measurements have been saved and processed, in order to compare them with the International Electrotechnical Commission (IEC) Standard 601-1-2 (IEC, 2002) and the ICNIRP-98 standard (ICNIRP, 1998) (see Fig.2 and Fig.3). A Geographic Information System (GIS) has been used to represent obtained data (Giannopoulou, 2008).



(a)



(b)

Fig. 2. E Field reference level of ICNIRP 98. Fig. 2-a-frequency band in RadMan XT and Fig. 2-b frequency band in SPY 120

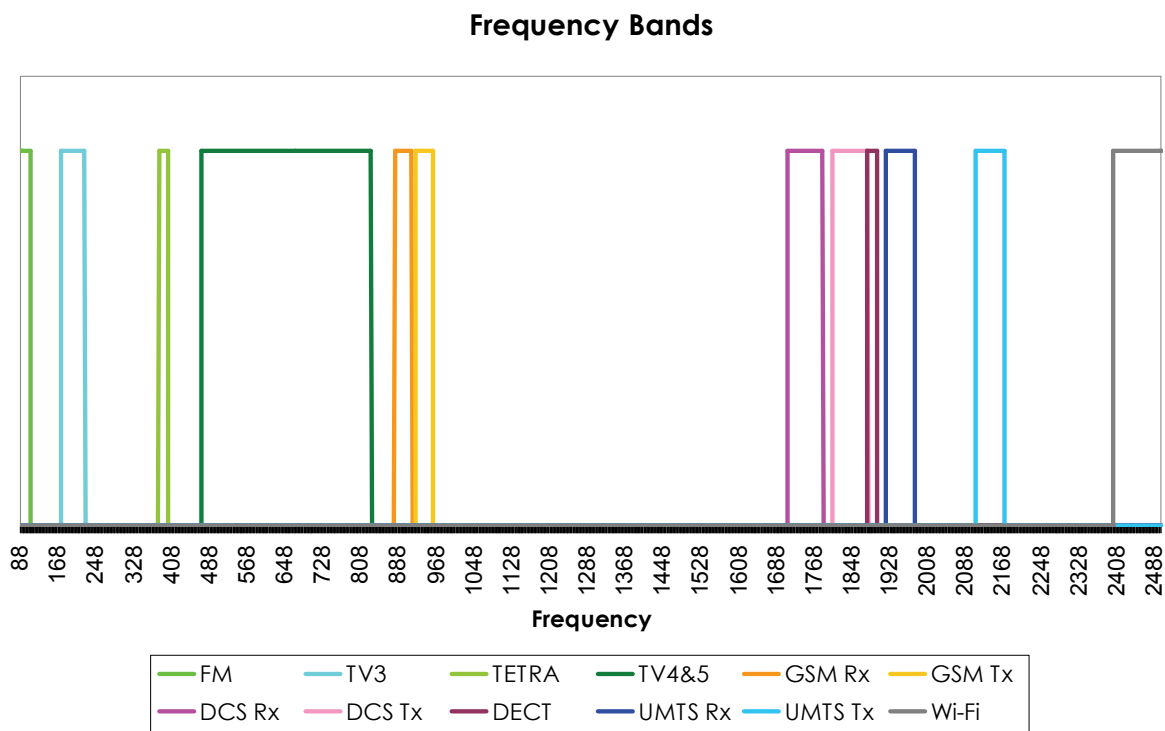


Fig. 3. Distribution of the 12 frequency measurement bands of ANTENNESSA EME SPY 120

Finally, an ad hoc study was performed by means of a spectrum analyser Rohde & Schwarz FSH6, obtaining the fundamental frequency, harmonics, emission power, signal characterization, identification of unknown signals, signal monitoring and field strength measurements. Its characteristics are: Frequency range: 100 kHz to 6 GHz, Detection limits: -80 dBm to +20 dBm, Resolution band: 100 Hz to 1 MHz.



Fig. 4. Spectrum analyzer Rohde & Schwarz FSH6

4.2 Measurements in laboratory

Measurements of GSM and DECT equipments and a microwave oven have been performed. These measurements have been made in far field conditions, using the Narda Broadband Field Meter NBM-550 with the isotropic probe for electric field 1891 (NBM). The frequency range of the probe goes from 3 MHz to 18 GHz and it can measure from 600 mV/m to 1000 kV/m.



Fig. 5. Narda Broadband Field Meter NBM-550

For the GSM technology, four different measurements have been performed. The first one was made with a Nokia 6230 and Orange card, the second one with the same cellular phone but a Vodafone card, the third one with a Siemens M55 with a Movistar card and the fourth one with a Samsung SGH-E250 and an Orange card. The Siemens phone is approximately 5 years old, the Nokia is 2 years old and the Samsung is about 4 months old. Measurements have been started at a distance of 3 meters, moving closer to the dosimeter at intervals of 0.5 meters until arriving at a distance of 0.5 meters (to keep the far field condition). At each distance, 4 measurements have been taken, rotating the cellular phone 90° every time. Measurements have been performed in two configurations: during the start of the call to that mobile and during a period of conversation, for 50 seconds each measurement. In the end, 48 measurements have been taken for each cellular phone.

DECT technology has been measured with two different models of phones, Siemens Giga Set A260 and Telefonica Famitel Novo. The procedure of the measurements is the same one as explained for the cellular phones, but the measurements have been repeated twice, once measuring the terminal and also measuring the base. At the end, 96 measurements have been taken for each wireless phone. A similar procedure has been adopted for measuring the microwave oven. The time of measurement has been reduced to 30 seconds, and the microwave oven has been measured in 2 angles of rotation with the same protocol explained before. Finally 12 measurements have been recorded for the microwave oven.

## 5. Results

Global results reported from homes studied in the metropolitan area of Madrid were analysed observing the contribution of the 12 frequency bands. Measurements made in Madrid are mapped and the maximum peak obtained in each house with the ANTENNESSA EME SPY is represented. Data from these measurements has been saved and processed, in order to compare them with the International Electrotechnical Commission (IEC) Standard 60601-1-2 and the ICNIRP-98. Then, results obtained with some of the electronic RF devices tested in laboratory will be shown.

### 5.1 Results of measurements in urban homes

Measurements made in Madrid during the years 2007 and 2008 are shown in the map (see Fig.6) The maximum peak obtained in each house with the ANTENNESSA EME SPY is

represented in this map. Values are normalized according to the standard ICNIRP 98. The range of these values goes from 0 to 1.51, in those cases where the value limit has been gone beyond this range.

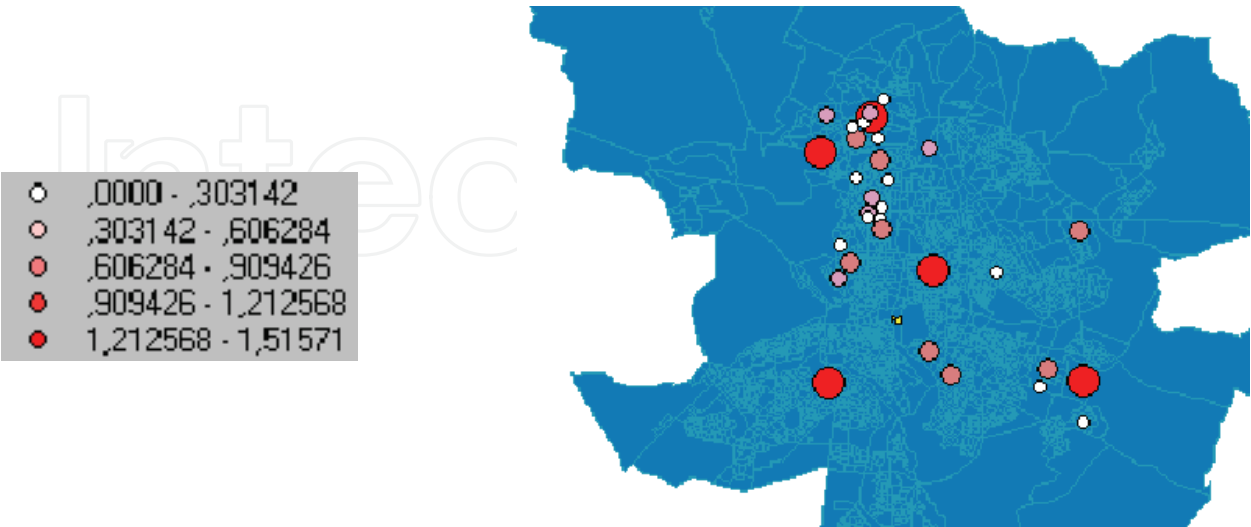


Fig. 6. Maximum peaks found (V/m)

According to the technology that causes the E Field, the distribution of number of peaks >10% ICNIRP in each home is displayed in Fig. 7. As it is shown, most of the peaks occurred because of the GSM or DCS technology. Nevertheless, in those cases where there are many peaks, the technologies causing this are FM, Wi-Fi or DECT.

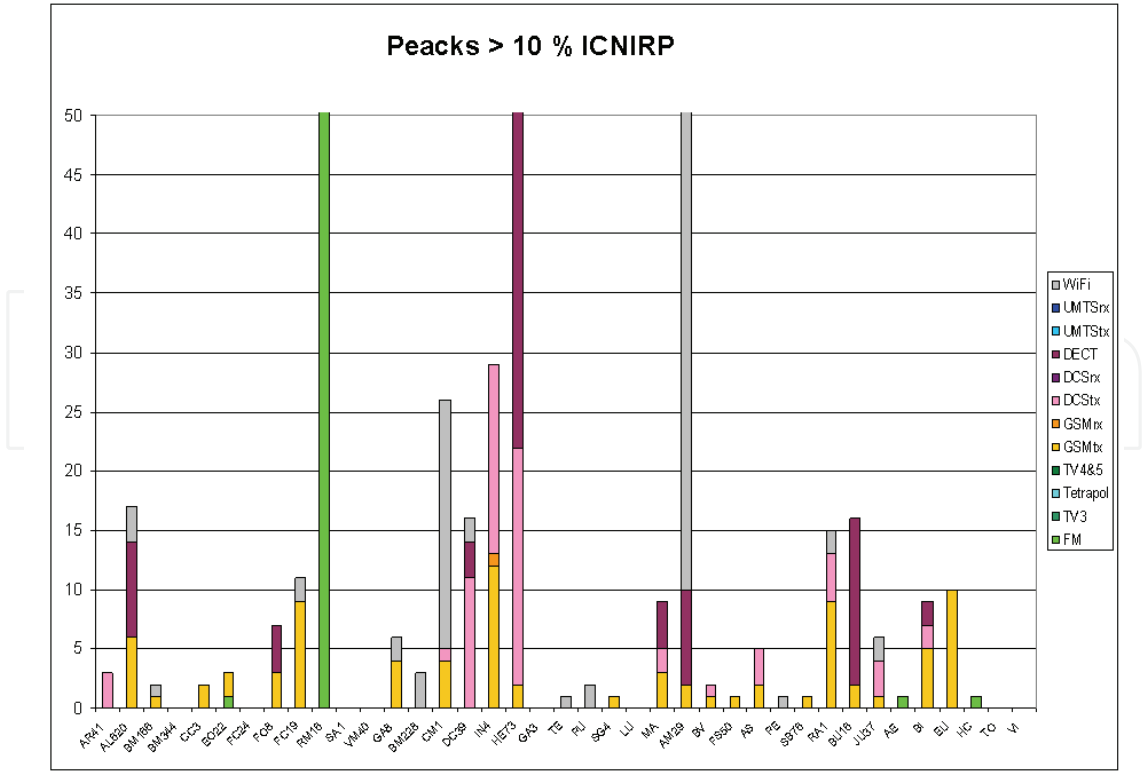


Fig. 7. Number of peaks obtained according to the technology



According to the IEC Standard 60601-1-2, a maximum E field of 3V/m is set for non-life supporting devices. Representation of the peaks higher than 3 V/m is shown in Fig. 8. As we can see, in most cases the value found corresponds to the maximum value that the dosimeter can measure (5.02 V/m). This means that these peaks are probably higher than 5.02 V/m although the dosimeter is not able to measure them.

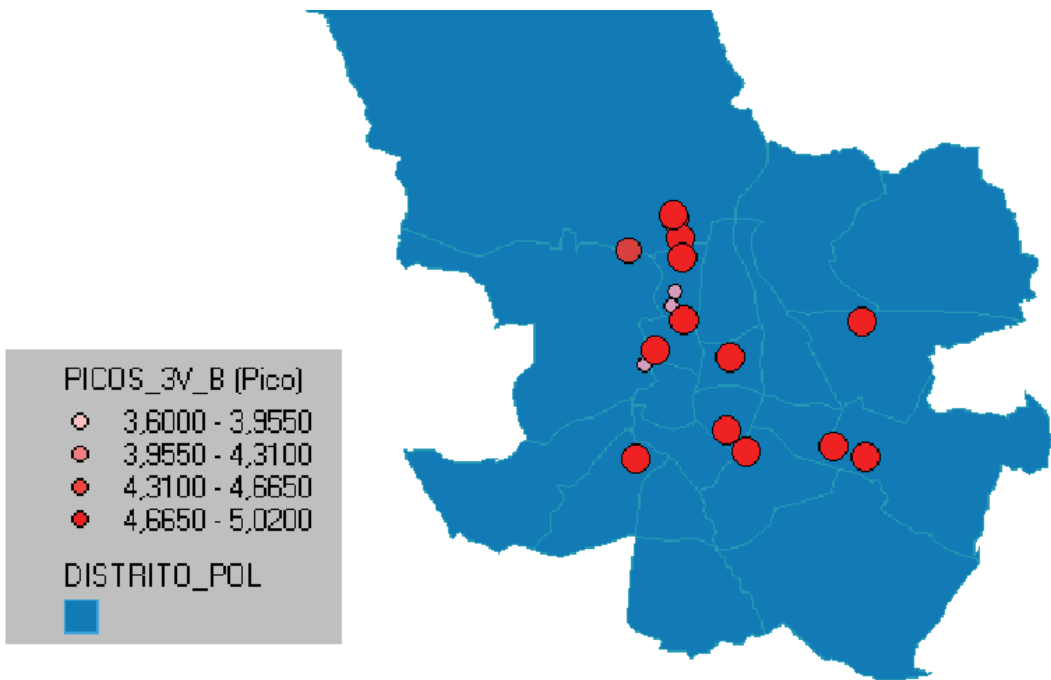


Fig. 8. Peaks higher than 3 V/m

Regarding the results obtained with the wide band dosimeter RadMan XT, no peak higher than 10% ICNIRP has been observed in any measurement. The difference between the results obtained with the dosimeter ANTENNESSA EME SPY 120 and the dosimeter RadMan XT is that in this one, measurements are made in broadband (for the E field, from 1 MHz to 40 GHz) and they are not localized in one band. Therefore, peaks obtained are much higher when the frequency bands are narrower.

Results obtained with RadMan XT did not show any important peak in the houses studied, as it is a broadband dosimeter. Baseline levels are always below the 10% of the ICNIRP standard.

Service	Freq. band (MHz)	E (V/m)	Ref level IEC 60601-1-2 (V/m)	ICNIRP (%)
Wi-Fi	2400-2500	5.02	3	68
DECT	1880-1900	5.02	3	71
GSM tx	925-960	2.36	3	34

Table 1. E Field level of some services and reference level of Medical electrical equipment standard

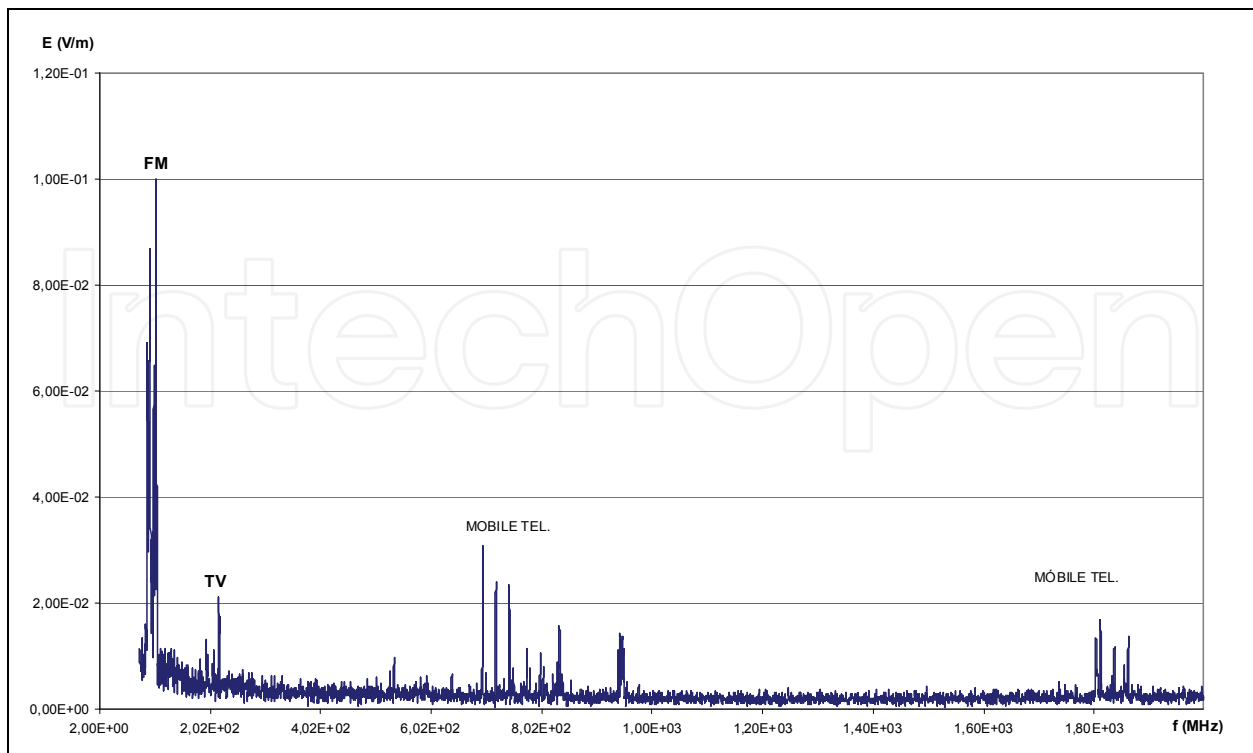


Fig. 9. Frequency composition of environmental EMF

Regarding the results obtained with the Spectrum Analyser R&S FSH6, frequency composition of environmental EMF in the area of observation is fixed by technologies used in the area. The presented frequency spectrum in Fig. 9 is typical for urban areas.

These results obtained with all the technologies measured are similar to other measurements of indoor passive RF-exposure of children (Decat et al., 2008). This study's conclusion was that within a radius of 1.60m, the exposure is substantially higher than the total field generated by all the indoor and outdoor wireless sources put together. These results are also in line with other work (Karpowicz, 2010) concluding that increased level of EMF, even EMF of level  $> 3 \text{ V/m}$  might exist in the vicinity of EMF sources and special attention is needed in case of propagation difficulties for mobile phone devices. A significant difference in the median level of registered E-field should be noted – the shorter the increased E-field in the environment, the lower the hazard of unwanted exposure results in both humans and electronic devices. Potential interferences could vary from one location to the next, depending on combination, type and even the electronic equipment in use.

## 5.2 Results of measurements in laboratory

The most characteristic results obtained in the laboratory are shown in this section. As explained before, all these measurements have been done with the Narda Broadband Field Meter NBM-550 with an isotropic probe for the electric field.

Fig.10-a) shows the results obtained from the Nokia 6230 mobile phone terminal during the start of a call. The maximum, average and minimum electric field can be observed. The peak has a value of  $3.5 \text{ V/m}$  approximately, while the distance is 0.5 meters. Fig.10-b) shows the strength of the E-field depending on the position of the phone. Results on the electric field during a conversation are not shown because the levels of the field are lower than those of Fig.10-a).

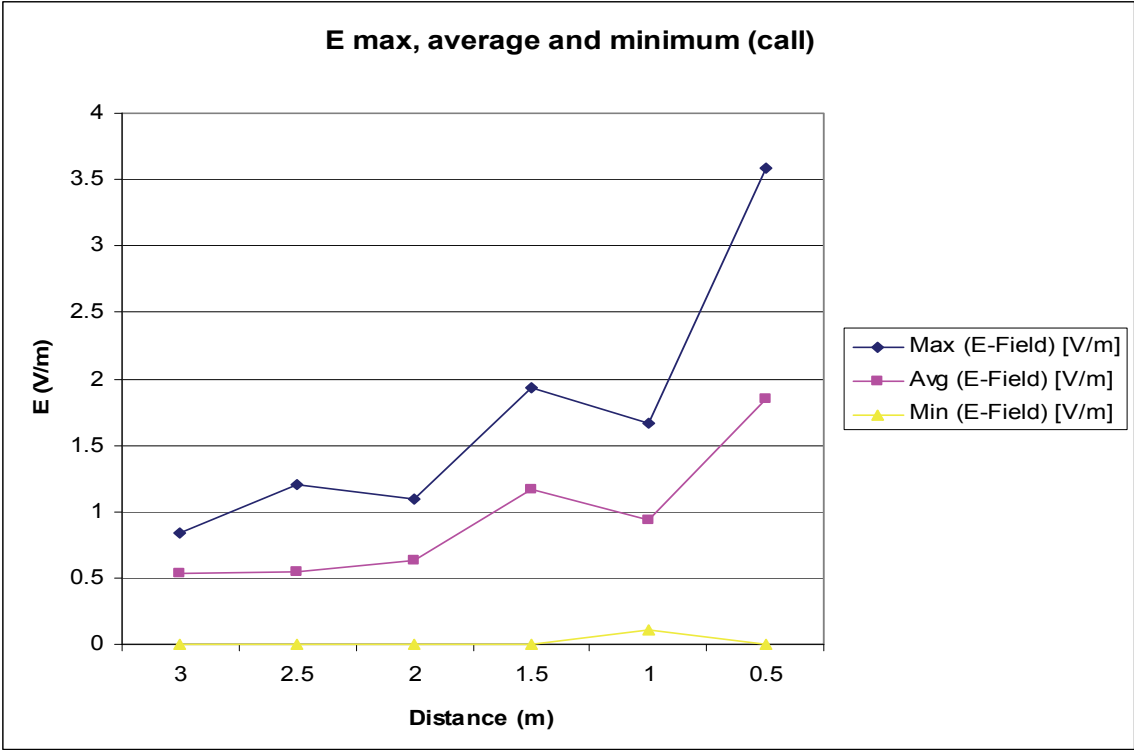


Fig. 10. a) Maximum, average and minimum E field measured, during a starting call to the Nokia 6230.

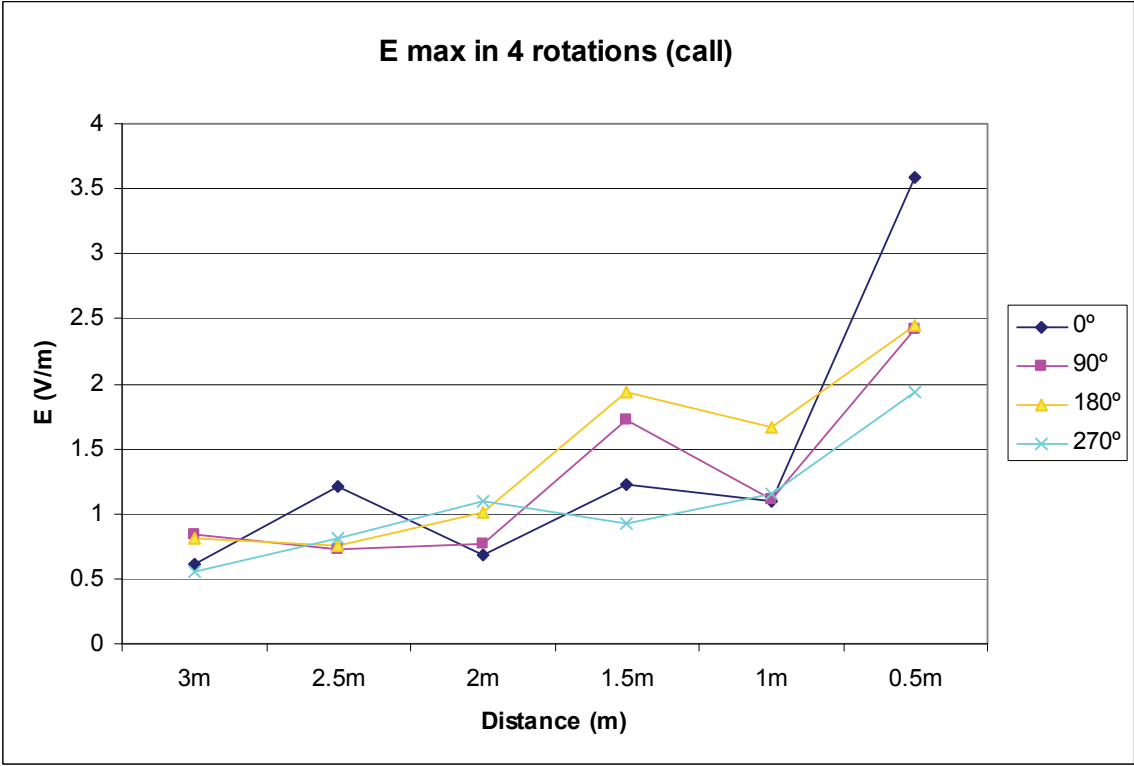


Fig. 10. b) Maximum E field according to the position of the phone, during a starting call to the Nokia 6230.

Comparing results obtained from the four performed experiments, we can observe that the oldest cellular phone (Siemens M55) is the one with the highest peaks of E field, reaching 7 V/m at a distance of 0.5 meters. The other experiments reach values of about 3.5 or 4 V/m at the same distance (see Fig. 11-a). In Fig.11-b) the SAR (specific absorption rate) for each model of phone measured is shown. In this case, the newest phone is the one that has less SAR. According to the distance from the different antennas (Orange, Vodafone and Movistar) to the laboratory, the Vodafone one was the nearest (266 meters) while the Orange and Movistar are at 468 and 462 meters respectively. Observing the data in the figure, the distance to the antenna is not relevant because the phone with the Vodafone card has the same levels as the same one using the Orange card.

The following evaluation was done with the E field radiated by a microwave oven. This microwave oven was chosen among those measured with the ANTENNESSA EME SPY, because of its high levels present (approximately 70% of the ICNIRP standard, at a distance of 0.5m). In this case, the levels are already higher than 3 V/m at a distance of 2.5 meters, reaching 7.8 V/m at 0.5 meters. As we expected, at the back of the oven, the fields emitted are a bit lower (see Fig. 12).

Fig. 13 shows the results obtained from the two different models of wireless phones with DECT technology. Measurements have been made in call and conversation mode, measuring separately the handset and the base. Levels have reached a maximum of 1.2 V/m for the handset and 1.4 V/m for the base, so they are always under the levels specified by the standard 60601-1-2 for immunity for medical devices.

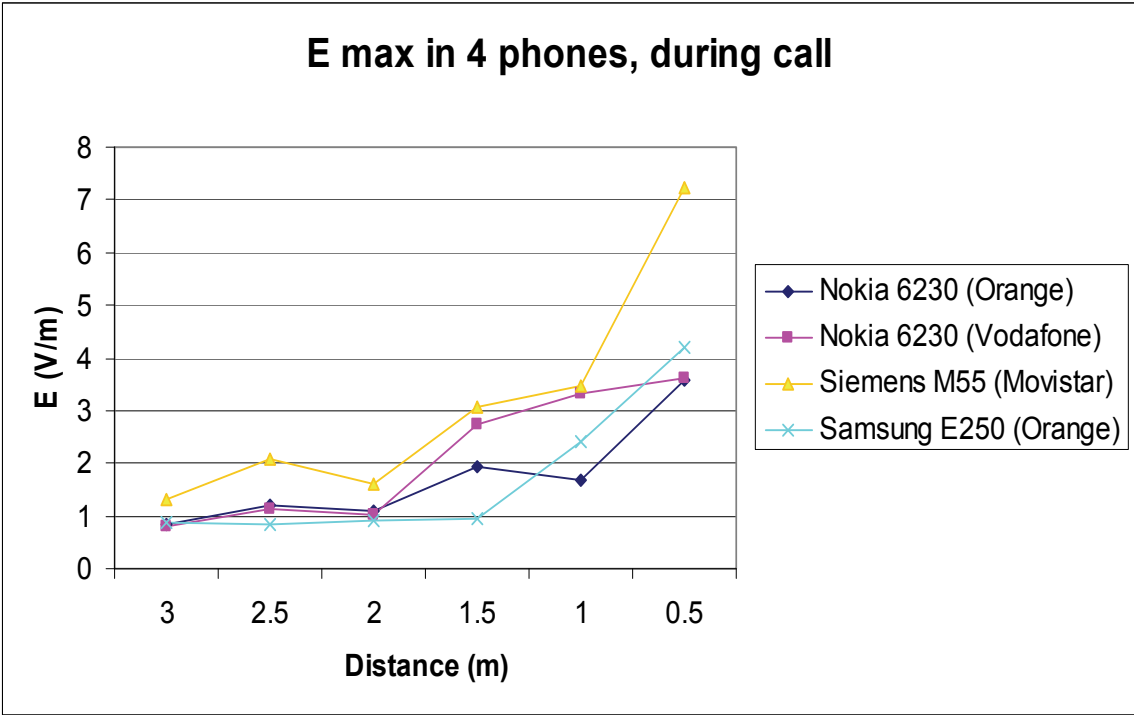


Fig. 11. a) Maximum E field for the 4 experiments with cellular phones.

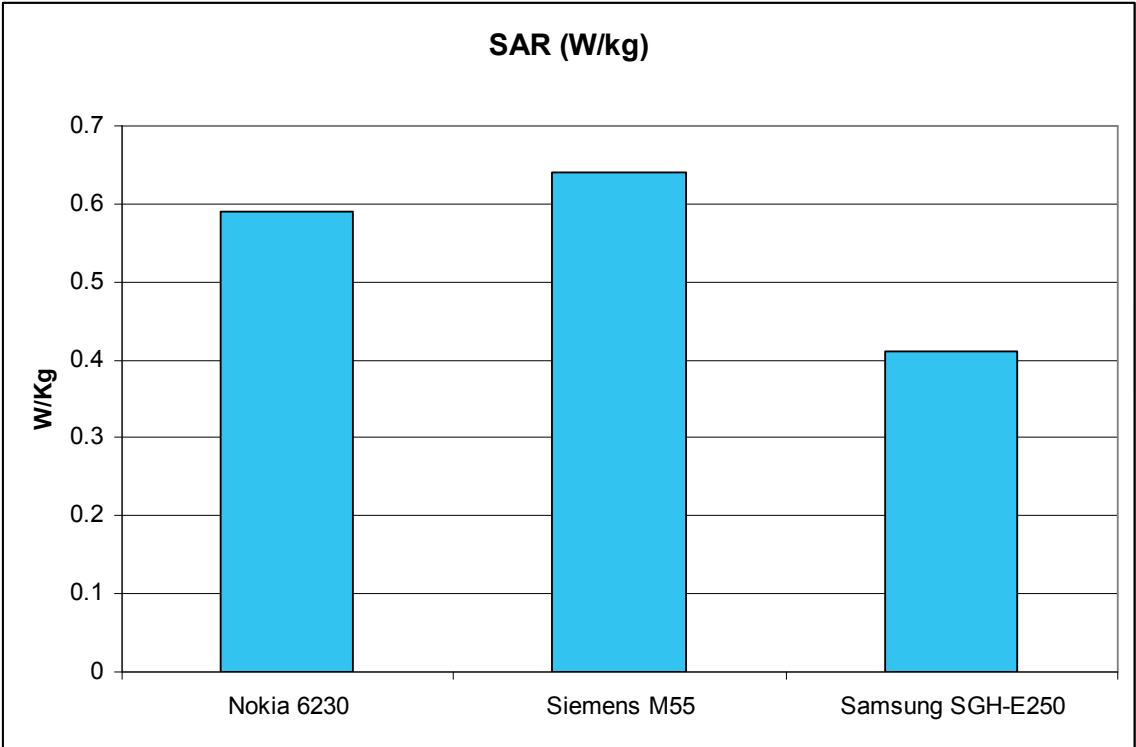


Fig. 11. b) SAR of each model.

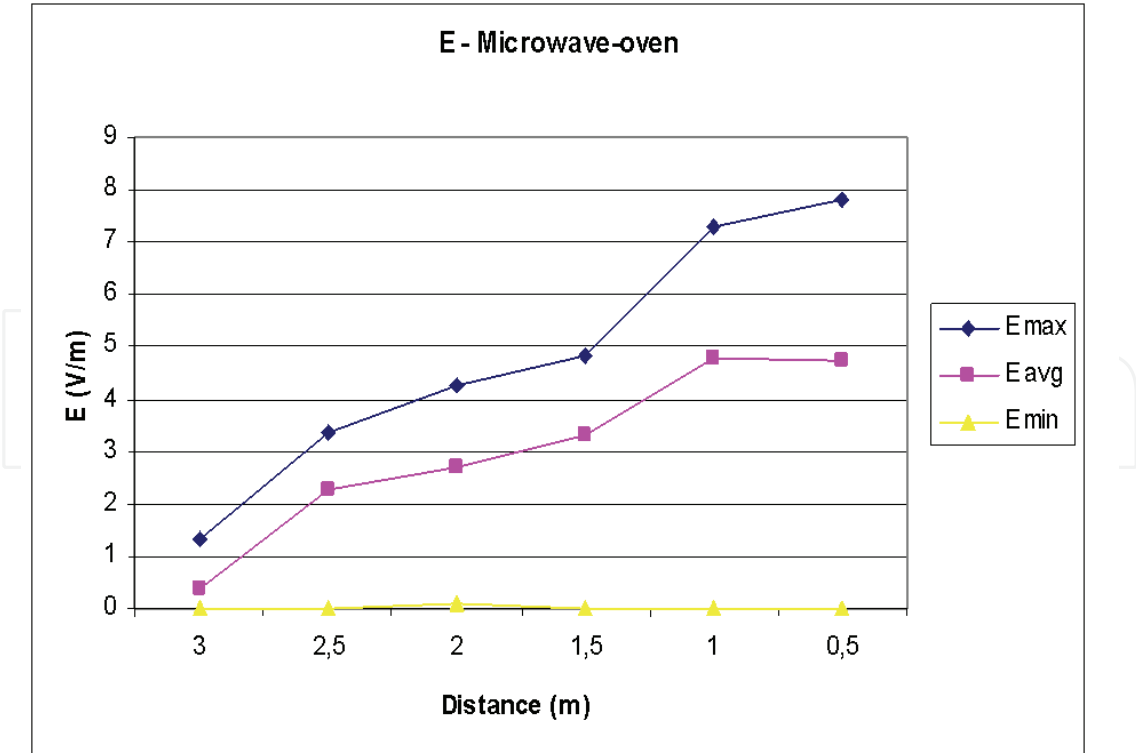


Fig. 12. a) Maximum, average and minimum E field measured in a microwave-oven.



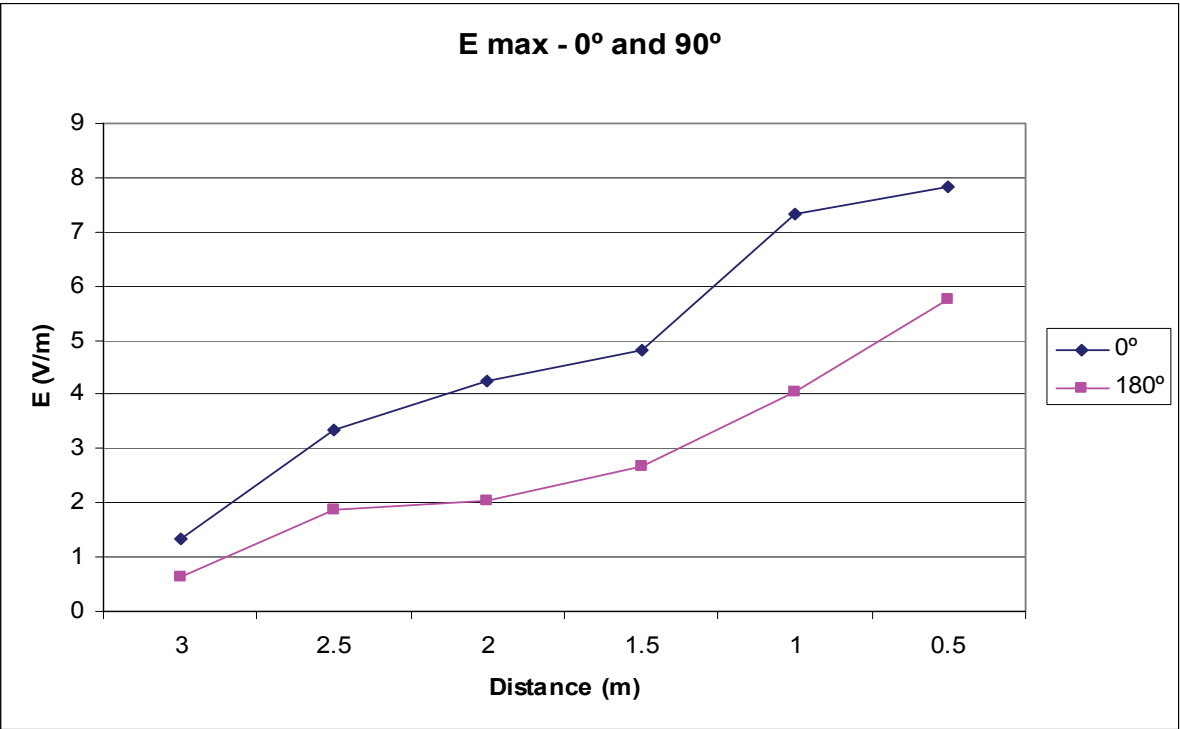


Fig. 12. b) Maximum E field measured in 2 positions (front and back side of microwave oven)

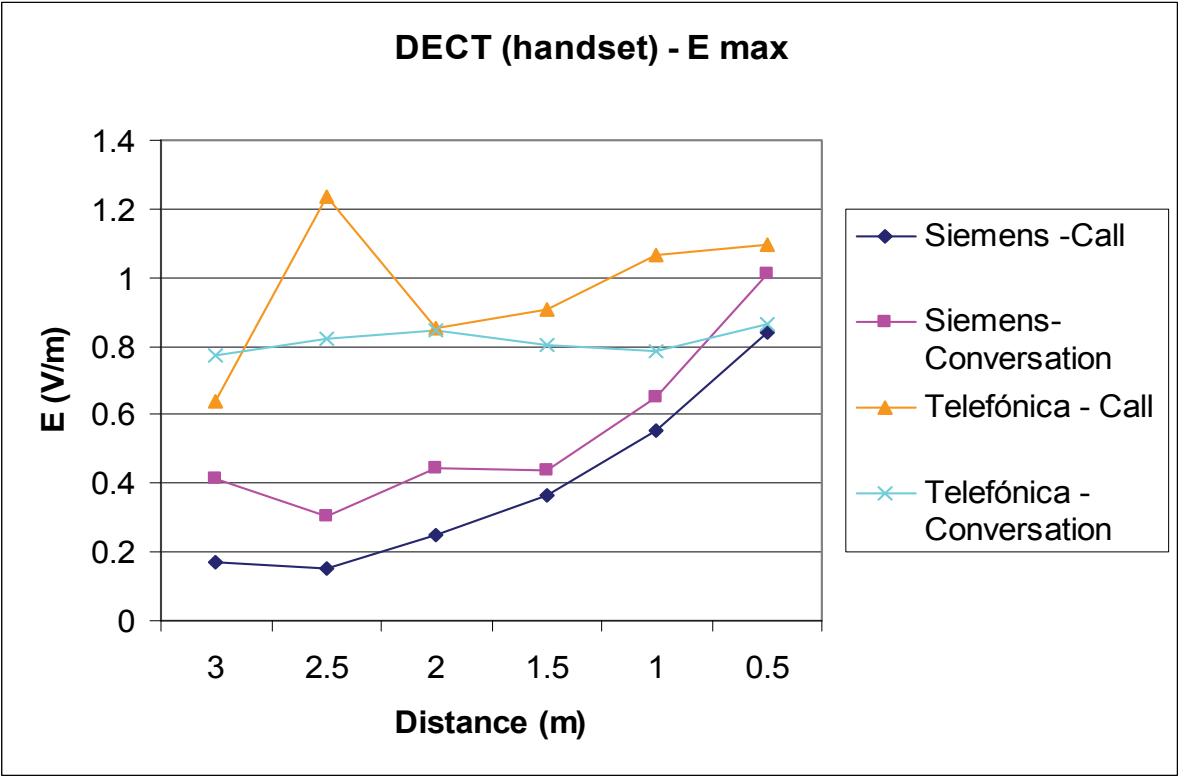


Fig. 13. Maximum E field measured in two different models of wireless phones with DECT technology. Fig.13-a) in the handset

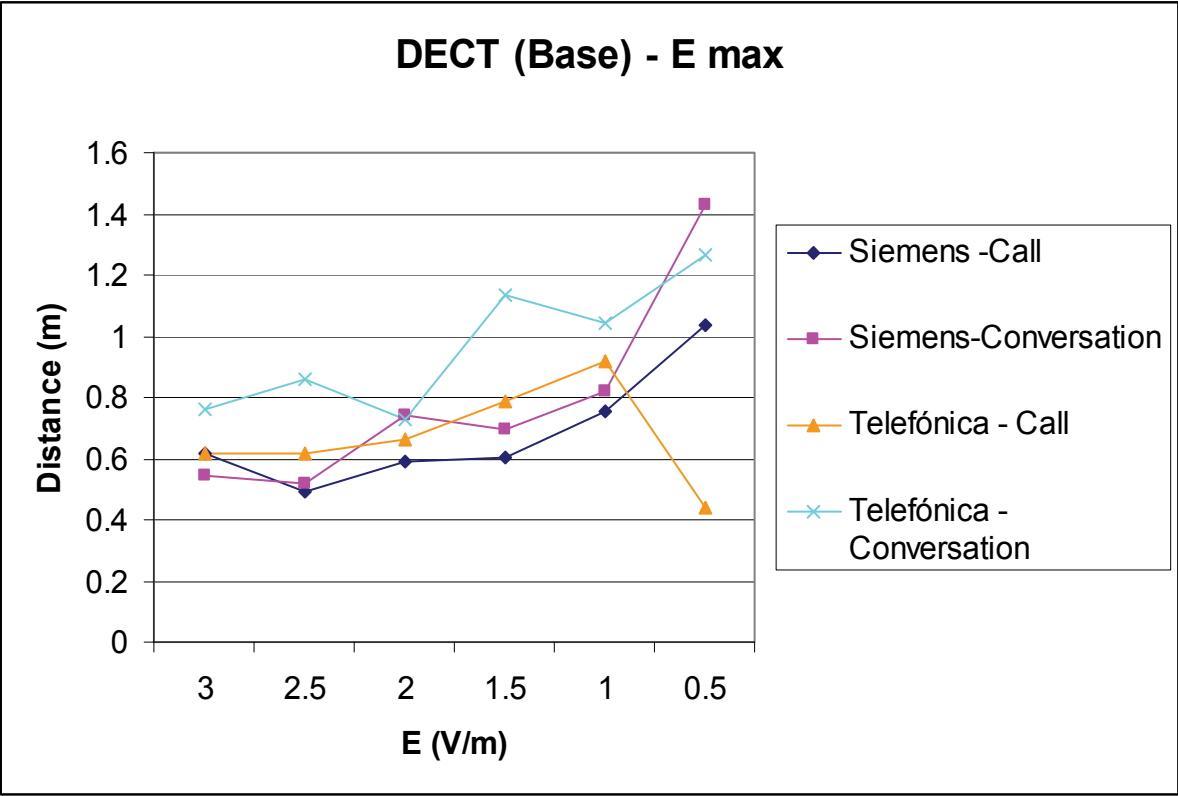


Fig. 13. b) in the base station.

6. Discussions

Real time, reliable, safe, interoperable, fully integrated wireless medical systems are expected to be widely deployed for home and personal care. The new solutions must be considered issues with respect to electromagnetic compatibility and regulatory compliance (COMAR, 2005).

With the increased use of radio networks in the proximity of home medical devices, it will be important to determine the zone/s with higher levels of exposure as well as the relative contribution of auxiliary antennas that may be installed in the proximity (even with no license or not in a permanent basis).

The European Union has recognized the importance of EMC, and all products sold in Europe must now meet the essential requirements of the EMC Directive. The IEC electro medical devices standard, IEC 60601-1-2 (IEC, 2002), permits radiated-immunity testing of non-life-supporting and life-supporting equipment from 80 MHz to 2,5 GHz, and Safety Distance Limits for patient-coupled devices.

ICNIRP-98 and the Council Recommendation 1999/519/EC (European Commission, 1999), of 12 July 1999, on the limitation of exposure of the general public to electromagnetic field (0

Hz to 300 GHz) outline a set of basic restrictions and reference levels for the Member States to follow. Compliance with these guidelines may not necessarily preclude interference with, or effects on, emerging home telemedicine systems.

According to the research results observed by the authors, the base line EM levels are below the security threshold stated by ICNIRP-98. It means E field levels in urban home environments are apparently safe in accordance with health and safety requirements, regarding the patients' exposure to the risks arising from electromagnetic fields. Nevertheless, data compared with ICNIRP standard for human exposure show high levels in Wi-Fi, DECT and GSMtx bands. That can be seen in Fig.10, Fig.11, Fig.12 and Fig.13.

The detected presence of quite high levels in some frequency bands reveals the need to pay attention to potential Electromagnetic Interference (EMI) problems in particular cases, where there is the possibility of RFI problems with medical devices. It makes it necessary to assess local EM conditions regarding home telemedicine risk analysis.

Proper design and installation of medical devices, coupled with proper characterization and management of potential sources of electromagnetic emission in the local environment, can protect against EMI.

## 7. Conclusion

Mobile phone technology relies upon an extensive network of fixed antennas, or base stations, relaying information with RF signals. Other wireless networks that allow high-speed internet access and services, such as Wireless Local Area Networks (WLANs), are also increasingly common in homes, offices, and many public areas (airports, schools, residential and urban areas). As the number of RF sources rises; so does, in some cases, the RF exposure of the population, depending on a variety of factors such as the proximity to the transmitter and the surrounding environment.

International and national bodies have set different limit values for permissible electromagnetic radiation levels in various standards and regulations. The European Union has recognized the importance of EMC, and all products sold in Europe must now meet the essential requirements of the EMC Directive. Compliance with these guidelines may not necessarily preclude interference with, or have effects on, emerging telemonitoring applications used at home outside of hospitals.

New wireless solutions must be considered issues with respect to electromagnetic compatibility and regulatory compliance. It would make a local assessment necessary and risk analysis prior to the installation of a home telemonitoring application. The degree and type of EMF exposure currently encountered in domestic settings needs to be characterized, in order to ensure that the equipment operates properly and exposure guidelines are not exceeded.

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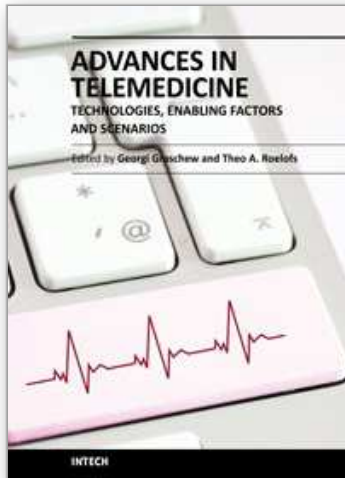
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## **Advances in Telemedicine: Technologies, Enabling Factors and Scenarios**

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Innovative developments in information and communication technologies (ICT) irrevocably change our lives and enable new possibilities for society. Telemedicine, which can be defined as novel ICT-enabled medical services that help to overcome classical barriers in space and time, definitely profits from this trend. Through Telemedicine patients can access medical expertise that may not be available at the patient's site. Telemedicine services can range from simply sending a fax message to a colleague to the use of broadband networks with multimodal video- and data streaming for second opinioning as well as medical telepresence. Telemedicine is more and more evolving into a multidisciplinary approach. This book project "Advances in Telemedicine" has been conceived to reflect this broad view and therefore has been split into two volumes, each covering specific themes: Volume 1: Technologies, Enabling Factors and Scenarios; Volume 2: Applications in Various Medical Disciplines and Geographical Regions. The current Volume 1 is structured into the following thematic sections: Fundamental Technologies; Applied Technologies; Enabling Factors; Scenarios.

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