Chapter 8

Short Range Technologies for Ambient Assisted Living Systems in Telemedicine: New Healthcare Environments

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Additional information is available at the end of the chapter

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1. Introduction

The increasing average age of people and the consequent rise of chronic diseases will result in a growth in the need for assistance and healthcare within the coming years. Nevertheless, this is not the only challenge that developed countries face regarding healthcare services. There is an increasing demand for outpatient care accessibility, maintaining and restoring health, as well as maximizing the independence of patients [1], [2].

While the broader field of telemedicine and/or telehealth has been used in various forms for many years, Ambient Assisted Living (AAL) systems in Telemedicine are a relatively recent innovation [3] and an emerging area of interest to service providers and consumers [4]. Smart environment is a rapidly evolving domain focused on providing personal care settings with the primary intent of supporting the patient rather than office visits with health professionals. AAL is used in a wide sense and encompasses the use of audio, video and other telecommunication technologies to evaluate patient status at a distance [5], [6]. Remote healthcare monitoring systems could aid in reducing costs and alleviating the shortage of healthcare personnel [1].

Additionally, the Internet has experienced a large growth over the past three decades, evolving from a network of a few hundred hosts to a platform linking billions of "things" globally [7]. The growth of the Internet shows no signs of slowing down and it has steadily become the cause of a new pervasive paradigm in computing and communications. This new paradigm enhances the traditional Internet into a smart Internet of Things (IoT) created around intelligent interconnections of diverse objects in the physical world. This approach enriches the AAL environment and offers new possibilities for healthcare [2].

Wireless connectivity is a feature of IoT, and is becoming increasingly used in AAL systems with intensive use of Short Range Devices (SRD) such as Radio Frequency Identification (RFID), Ultra Wide Band (UWB), Near Field Communications (NFC), Wireless Local Area Networks (WLAN), Bluetooth, ZigBee, telealarm buttons (social alarms) or domotic devices. These systems involve sensors, computing and communication devices working in increasingly dense electromagnetic environments. One emerging approach to improve 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 (EM) environment [8]. Electromagnetic Fields (EMF) are present everywhere in our environment and will continue to increase. 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 to the general public 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. Electromagnetic Interference (EMI) can be a serious problem for any electronic device, but working with medical devices can have life-threatening consequences. Practical commercial deployment of these wireless networks requires measurements of the Electromagnetic Compatibility (EMC), as a guarantee of lack of interferences 24 hours a day, seven days a week.

2. Antecedents / background

Improvements in medical technology and healthcare have helped people to live longer and with a better quality of life. Nowadays, our societies are facing new challenges in terms of economically and socially supporting their ever more costly welfare systems and increasing elderly population and chronic patients. The future of health care provision will see an exchange from centralized health care services, provided in doctors' offices, clinics, and hospitals, to ubiquitous and pervasive health monitoring in everyday life. The reason for this development is twofold. Firstly, demand for better, more comprehensive and proactive health care and health provision is steadily increasing. Long-term unobtrusive monitoring of biomedical signals to enable early-stage diagnosis of health issues represents a key component in proactive health care. Secondly, there is the requirement to mitigate increasing health care costs caused by the demographic changes of an aging society. By providing health services at a patient's home where the cost is lowest (as opposed to expensive clinical environments), large cost reductions seem to be feasible while at the same time providing a better quality of life [9]. New medical technologies and improvements in health information systems have benefited medical supply ordering and management, patient record administration, medical diagnosis, and the provision of patient services [10].

In recent years we are seeing great advances in all areas of technology from low-power electronics, Short Range Devices and sensor technologies to the development of new and

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original wired and wireless communication. These advances have already led to the development of new small-sized wireless medical and environmental sensors that are capable of monitoring the human body as well at its environment in a more efficient way. These advances in sensing, communication technologies and in software engineering make it possible to build new solutions for wearable healthcare systems and ubiquitous healthcare smart homes. With these systems, elderly people and those with pre-existing health conditions can remain in their own home, while healthcare providers can remotely monitor and advise them to improve their well being and provide them with quality healthcare.

Over the last few years, the number of short range systems has increased in residential environments. These systems provide a great variety of emerging applications such as tracking and mobile telecare and welfare, with the possibility of the inclusion of many types of conventional alarms (gas, smoke, flood, etc...). Short Range technologies provide direct benefits when applied to a healthcare environment. The main objective of these SRD is to communicate emergency situations due to domestic accidents or health emergencies. These are low-cost information gathering and dissemination devices and facilitate fast-paced interactions among objects themselves (vehicles, cell phones, habitats, habitat occupants), as well as the objects and people in any place and at any time [11]. The special implication of these devices with welfare and safety requirements involves a special interest in its operating conditions as well as in promoting correct habits of usage.

With the rapid advances in increasing computational performance while allowing for ever smaller integration sizes, on-body networks of wirelessly connected computing devices is becoming a reality. The vision of ubiquitous health (U-Health) care is addressed by this Body Area Network (BAN) and Body Sensor Network (BSN) technology [12]. As is shown in Figure 1, a network of interconnected Wireless Sensor Nodes (WSNs) in or around the body monitors a range of biomedical signals to assist in the detection and diagnosis of health - related problems.

In the emergent IoT approach, a wide range of SRD is used. Smart applications and services to cope with many of the challenges individuals and organizations face in their everyday lives, such as environmental and personal health remote monitoring systems. These applications would change the way societies and especially our healthcare system function and thus would have a big impact on many aspects of people's lives in the years to come. IoT is not a mere extension of today's Internet or Internet system. It represents intelligent end-to-end systems that enable smart solutions, and, as such, covers a diverse range of technologies, including sensing, communications, networking, computing, information processing, and intelligent control technologies. Furthermore, technical advances in miniaturization and wireless communications have enabled applications of wireless sensing and biomonitoring, using devices that are now available for general use by healthcare professionals, patients and caregivers [7], [9].

These solutions could significantly reduce the cost of welfare systems while maintaining existing hospitals and dedicated centers for people who cannot benefit from these Information and Communications Technology (ICT) solutions. U-Health Smart Home, a home equipped with ICT to support people directly in their homes, has been identified by governments and

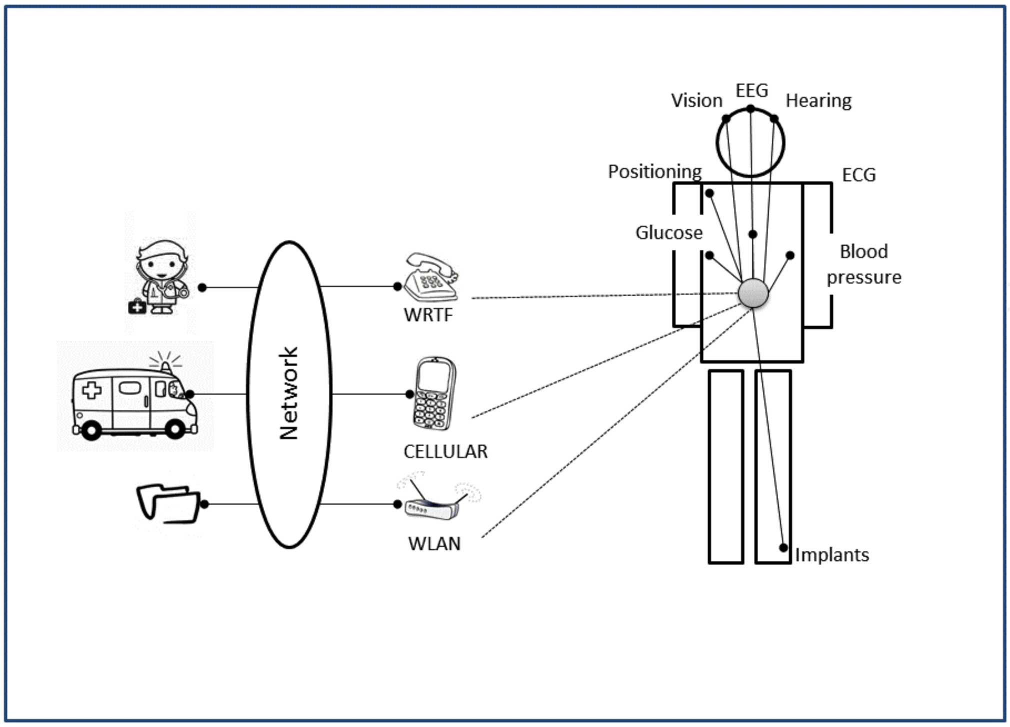

Figure 1. Ubiquitous health monitoring: a Body Area Network (BAN), wireless sensor nodes, monitoring biomedical signals and remote health assistance (WRTF: wired telephony service)

medical institutions as an important step toward financial savings, as well as a technologically and socially acceptable solution to maintain the viability of the welfare system. However, there are several obstacles to the acceptance of these solutions, some are technological, and others are more related to human acceptance in terms of comfort and business value.

3. Current state of knowledge and main objectives

a. Research objectives

Given the current pace of implementation, this work reviews the literature regarding the use of SRD in healthcare, both systematically and comprehensively, following an innovation decision framework. We provide a brief introduction on these technological options, the current challenges, and the improvements that occur as a result of the use of this new technology. Then we analyze the specific uses of SRD technology in different areas of healthcare. The potential benefits are evaluated as a driver that will promote its adoption, and possible barriers to their acceptance are identified [13].

In this work the EM conditions have been analyzed and the radiation patterns of several models of social alarm devices have been obtained. Given the increasing use of domiciliary telealarm devices, and the non-existence of previous studies of the working conditions and the emission levels, this paper analyzes two of the aspects that have to be considered to assure a proper, reliable and safe usage of these systems. The first is the compatibility with other communication networks and implanted electric devices. The second is the compliance with exposure levels threshold, to quantify and analyze the risk of exposure caused by the use of these devices.

b. Current state of knowledge

For some years now short range technology has been considered a very promising option to cope with healthcare monitoring challenges. Consequently, this work aims to show the new technological advances and which factors might explain the penetration rate in healthcare.

The appearance of smart phones has been the major developmental breakthrough in the field of wireless personal area networks (WPAN). This has conditioned to a large extent the proliferation of devices in AAL systems that use the aforementioned smart Phones as a gateway to the network.

Factors like, accessibility, price, processing and communication capacity, as well as the use of cameras, navigation systems, such as the Global Positioning System (GPS), and accelerometers allow for a great flexibility in the development of further applications. The increasing use of operating systems, such as, Android, iOS, Symbian or Windows Phones that use the Software Development Kit (SDK) allow the development of certain applications to became easier and easier. As a result, networks that are compatible with the smart phones (Bluetooth, Wi-Fi o NFC) are currently the most frequently used by devices that are found within personal area networks in the healthcare environment.

Within the area of AAL three types of wireless networks need to be considered, Wi-Fi networks, domestic networks and networks made up of social alarm devices (SAD). Wi-Fi networks because of their widespread usage, reduced price and operability with other such as PCs, tablets or smart phones are a very attractive proposition for network usage within assisted environments, without forgetting their main advantage, that of internet access. Disadvantages could be the high energy consumption and time required to establish a connection.

With regard to SAD, they are perhaps today the most frequently installed device within elderly households. Within Spain it is estimated that there are currently around 300.000 SAD and that 4% of Europeans of more than 65 years of age, have access to a device of this type [14]. The platforms of SAD are suitable for integration with other devices within the assisted environments. SAD work on a frequency of 869.2-869.25 MHz and operate under the guidelines of the Commission Implementing Decision of 8 December 2011 (2011/829/EU) [15]. Currently, as well as wristband and chain alarms there are devices to detect falls, to monitor lifestyle, to monitor biological parameters, to detect technical alarms (such as smoke alarms, flood alarms or gas emissions), medicine dispensers and many other systems and technical aids.

Within the household wireless systems the Z-Wave technology stands out. In comparison to Wi-Fi, the device runs on batteries and the speed of transmission is lower, from 9.6 Kbps to 40 Kbps. Z- Wave operates in Europe on a wavelength of 868 Mhz.

As is shown in Table 1 with regards to the possible wireless communication options the vast majority use Bluetooth for data communication, differentiating between those that use the conventional form of Bluetooth and those using the newer low consumption version. You can see that there are several devices that are certificated by Continua, which ensure compatibility of data between platforms. Far behind, we can find those that use Wi-Fi as a form of wireless communication and finally you can find some that operate with Zigbee o with ANT.

Device Type	Model	Connectivity	Image	Autonomy	Memory	URL
Blood glucose	Allmedicus Gluco AGM300	Bluetooth Health Device Profile (HDP)[1]		2*AAA batteries / 5000 tests	250 tests	www.allmedicus.com
Oxygen Saturation	Nonin 9560	Bluetooth V2.0 Secure Simple Pairing (SSP), HDP[1]		2*AAA batteries / 600 spot checks	9560 tests	www.nonin.com
Blood Pressure	iHealth IH-BP7	Bluetooth V3.0+ Enhanced Data Rate (EDR), Class 2 SPP		1*3.7V battery Li-ion/ 100 measur. per charge	....	www.ihealth99.com
Blood Pressure	A&D UA-767 PBT-C	Bluetooth V2.1, Class 1, HDP[1]		4 *AA alkaline batteries. / 300 uses	40 measur.	www.aandd.jp
Blood Pressure	Omron BP792IT	Bluetooth V2.1+ EDR, Class 2, HDP[1]		4 *AA alkaline batteries. / 300 uses	Up to 84 per user	www.healthcare.omron.co.jp
Blood Glucose & Blood Pressure	Fora DUO D40 a/b/g	Bluetooth HDP / GPRS		4 *AA alkaline batteries, recharg. batt. /	864 tests	www.foracare.ch
Ear Thermometer	Fora IR20b	Bluetooth		2*AAA / 1000 tests	10 measur.	www.foracare.ch
Spirometer	SDI Astra 300	Bluetooth V2.0		2*1,5V alkaline batteries /	1100 tests	www.sdidiagnostics.com
Spitopmetry and Oximetry	MIR SpiroBank II	Bluetooth		4*AAA & CR2032 / 10 years Mem-Batt.	6000 tests	www.spirometry.com
Peak Flow meter	Corsciensce A M1 +BT	Bluetooth		3 * AAA /....	490 tests (approx)	www.corscience.de
Peak flow meter	Vitalgraph Asma-1 BT	Bluetooth		2*AAA /....	600 tests	www.vitalograph.com
ECG 12ch	Corscience BT-12	Bluetooth SPP Class 2		2*AA batteries / used constantly: 14 h approx.	....	www.corscience.de
ECG 1ch	Corscience CorBELT	Bluetooth		2*AA Batteries / used constantly 24 h approx	....	www.corscience.de
ECG 6ch	SECA CT321	Bluetooth dongle		2 rechargeable L-Ion batteries /	....	www.seca.com
Monitor (17 Health Parameter)	VESAG Health Watch	IEEE 802.15.4 ZigBee		.... / 60 to 72 hours standby time	....	www.vesag.com
Monitoring device: ECG, Heart Rate …	Zephyr BioHarness 3	Bluetooth V2.1 + EDR Class 1		lithium cell / transmitting 24 h	500 hours	www.zephyr-technology.com
Heart Rate, Respiration Rate.	Isansys LifeTouch HRV011	ANT Ultra low-power wireless (2.4GHz)		.... / up to 5 days	....	www.isansys.com
Heart Rate	Polar H7 HR	Bluetooth Smart 4.0		CR 2025 battery / 200 h	....	www.polar.fi

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Device Type	Model	Connectivity	Image	Autonomy	Memory	REF
Pedometer	Omron HJ-721IT	Bluetooth V2.1+ EDR, Class 2, HDP[1]		lithium battery CR2032 / approx. 6	mem 41 days	www.healthcare.omron.co.jp
Weigh Scale and BMI	Omron BF-206BT	Bluetooth V2.1+ EDR, Class 2, HDP[1]		4*AA alkaline batteries /	approx. six months	www.healthcare.omron.co.jp
Weigh Scale and BMI	Fora W310b	Bluetooth		4*AAA /	135 measur.	www.foracare.ch
Weigh Scale	iHealth Scale	Bluetooth		4*AAA batteries /	200 measur.	www.ihealth99.com
Weigh Scale	Fitbit Aria	Standar 802.11b WI-FI		4*AA / six months	....	www.fitbit.com
Weigh Scale	A&D UC-321PBT	B/T ver 2.1 Class 1 SSP HDP[1]		4*AA alkaline batteries / 300 measurements	25 measur.	www.aandd.jp

Table 1. Comparative table of healthcare and wellness devices. (1) Continua Certified.

Regarding the use of Zigbee, and although not reflected in this table, you can find numerous examples of research project initiatives that have developed devices orientated towards healthcare or assisted environments and that use Zigbee as a channel for communications, however, it has to be noted that very few of these initiatives have reached the commercial markets.

In the following paragraphs, we will compare low energy Bluetooth, ANT and Zigbee.

ANT is an initiative that operates on a low power proprietary protocol, works on a 2.4 GHz frequency, and supports the following network topologies: point to point, tree, or mesh network topologies with a range of between 1 and 30 meters, reaching hundreds of meters or kilometers depending on the typology and number of nodes in the network. With regard to the consumption, it is estimated to be in terms of microamperes in latent mode (sleep) and 18 mA in wake mode (wake up) and in transmission. The transmission rates can reach 1 Gbps, but to maintain real lower consumption transmissions, only a few bytes per second are estimated with a possible lifespan of over three years.

Zigbee uses the standard IEEE 802.15.4 on a frequency of 2.4 GHz, as with ANT it can support point to point, tree, or mesh network topologies with a range of between 1 to 100 meters and reach extensive areas using mesh typology. With regard to consumption we are speaking of around 35 mA in transmission and in terms of microamperes when in sleep mode. The rate of transmission can reach 250 Kbps and have a lifespan of up to six months.

Finally, Bluetooth Low Energy (BLE) a feature of Bluetooth 4.0 under the standard IEEE. 802.15.1 within a short range (up to 50 meters) can only support peer to peer and star typology, and as a result can not establish a meshed network, with a data transmission speed that can reach up to 100 Kbps. It is possible to reach low consumption levels of around 25 mA in transmission, and microamperes when in the sleep mode. The lifespan of the battery may be calculated in terms of tens of days.

4. Methods

a. Review of literature

The ratio of penetration of SRD and its real effectiveness in healthcare remain unknown. This work reviews technological advances on SRD, produced from 2001 to 2011, to be applied in healthcare scenarios and mainly in AAL ones.

The research methodology employed for examining the adoption of SRD in healthcare has been divided into four phases: literature collection, categorization of the selected papers, analysis of the publications included in every category and results.

Search strategy

Both automatic and manual searches were carried out on professional databases including EMBASE, MEDLINE and PUBMED in order to identify relevant articles published between 2001 and 2011. The keywords used in the searching areas of title, keywords and abstract were a combination of 'short range device (or devices)', 'short range technology (or technologies)', 'radiofrecuency, 'rfid (and synonyms)', 'bluetooth', 'near field communication', 'wlan', 'uwb' and finally 'humans'. The number of papers initially located was 653. After eliminating duplicates and other inaccurate results, 378 were excluded and 275 were finally taken into account. Other systematic reviews carried out by different authors some years or months before were also very useful in identifying and including relevant studies not located by search engines.

Publication types reviewed were: Article, Article in Press, Conference Abstract, Conference Paper, Conference Review, Editorial, Erratum, Letter, Note, Review and Short Survey. Editorials, Letters, and Opinion Papers were excluded as well as those studies which dealt with ethical and legal aspects. No restrictions were imposed on the quality of the study design.

Data synthesis

Two authors independently reviewed the selected papers in order to classify them into one of the following categories at least:

- Electromagnetic compatibility
- Electromagnetic health risks
- Electromagnetic effects on the biological tissues
- Monitored environments
- Ambient assisted living
- Technological assessment

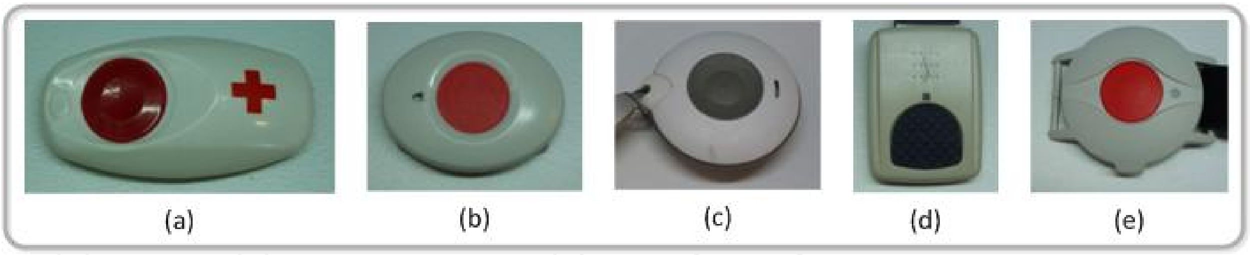

Figure 2. Selected models of social alarm devices: (a) AMIE+ Tunstall, (b) Neat Atom, (c) TX4 Bosch, (d) S37 TeleAlarm and (e) System 5000 Smart Call.

A more careful reading of the summaries showed that selected papers not always matched with the focus of this review. The found papers using search engines contained the words we were looking for but they were not always in the proper context. Search engines usually work using orthographical criteria and not semantic ones and this is a great weakness in automated searches.

b. Measurements: electromagnetic laboratory evaluation

The systems of social alarm devices consist of two operational units: the buttons that are worn by the users typically hung over the neck or attached at the wrist, and the fixed unit that is connected to the home phone. When the user is in a distress situation, he can push the button, a radio frequency signal will be transmitted to the fixed unit and an emergency phone call will be made to the monitor centre.

The buttons transmit a signal that typically consists of three pulses (depending on the model) at the frequency of 869.21 MHz. These are emissions in domestic settings that can affect the electromagnetic environments and can involve the increase in the exposure to electromagnetic fields of users, patients, medical workers and people in general.

Laboratory measurements have been carried out to characterize and analyse the RF emissions of the more extended social alarm devices. The objectives were to obtain the radiation pattern in order to identify the position when the electric field is at a maximum, and to calculate the power density and the Equivalent Isotropically Radiated Power (EIRP) for each of the tested devices.

The electric field strength and other parameters of the emissions of the device under testing have been measured to examine the compliance with exposure guidelines.

The performed environmental study of the working conditions of the social alarm devices helps to quantify the exposure of assisted people and to analyse the EMC of networks and equipment that operate in the surrounding areas.

For this work five models of social alarm devices were chosen from among the most frequently used in telecare monitoring activities. These devices AMIE+ Tunstall, Neat Atom, TX4 Bosch, S37 TeleAlarm and System 5000 Smart Call, are shown in Figure 2.

The measurements were performed in a semianechoic chamber, shown in Figure 3 and Figure 4. The room has dimensions of 9,76 m x 6,71 m x 6,10 m, the walls are lined with a foam based radiofrequency absorber material (RANTEC Ferrosorb300) specified to have a reflection/ absorption coefficient of -18 dB at the frequency of 869.21 MHz.

All of the measurements during this work were made in the far field region with respect to the sources. At 869.21 MHz, the wavelength is about 34 cm, which means the reactive near field extends to around 5.5 cm from the source (based on the usual $\lambda/2\pi$ criterion, where λ is the wavelength). The antennas of the social alarm devices are no more than around 5 cm in size, and they are integrated inside the casing device. Hence, the radiating near field extends no further than around 1.5 cm at 869.21 MHz (based on the usual $2D^2/\lambda$ criterion, where D is the maximum source dimension).

The devices tested were mounted on a manual positioning device with an EMCO 1060 motor, allowing the device to be rotated and permitted the measuring antenna to sample the radiation pattern at any angle. All the measurements were performed in vertical and horizontal polarizations; a positioner with an EMCO 1051 motor allows the changes of the position of the measuring antenna that is a VBAA-9144 Schwarzbeck biconical antenna with a frequency range of 80 MHz - 1 GHz. The instruments and devices used to obtain the radiation pattern are shown in Figure 3.

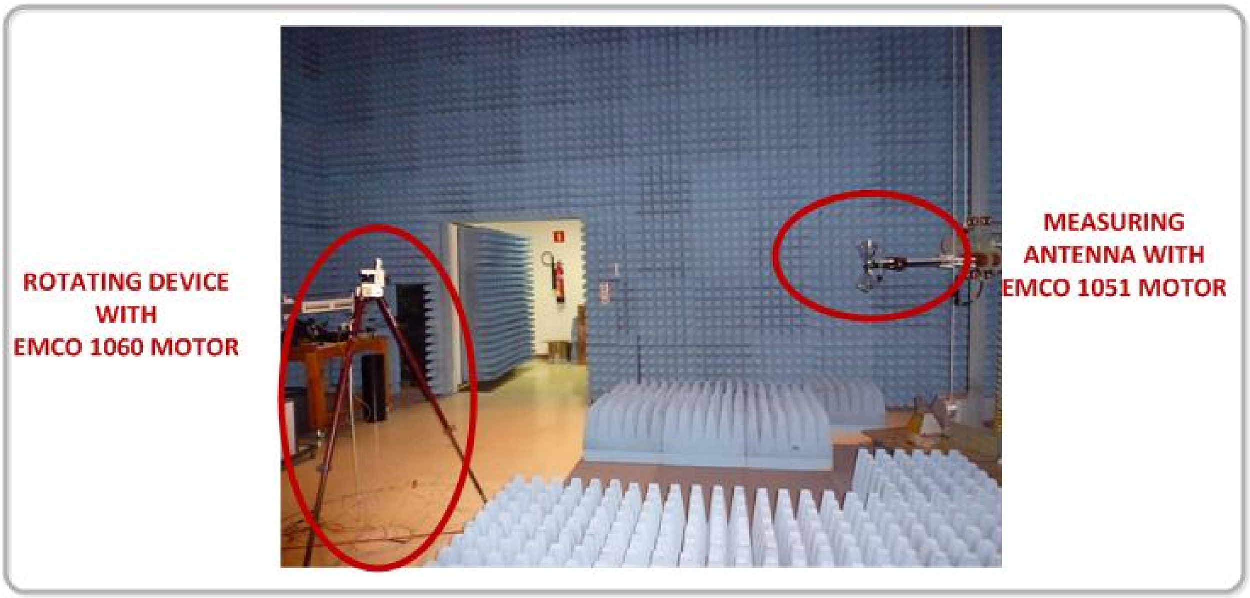

Figure 3. Measuring antenna and positioning devices to obtain the radiation pattern inside the anechoic chamber.

The radiation pattern of the models (a) AMIE+ Tunstall, and (b) Neat Atom are shown in Figure 4.

After obtaining the radiation pattern, the position of each tested device at which the electric field strength is maximum was fixed. In that position the electric field strength was measured as a function of distance in horizontal and vertical polarization in the far field region in steps of 10 cm, from 0.2 m to 1.7 m. The positioning device used to determine the distances was a

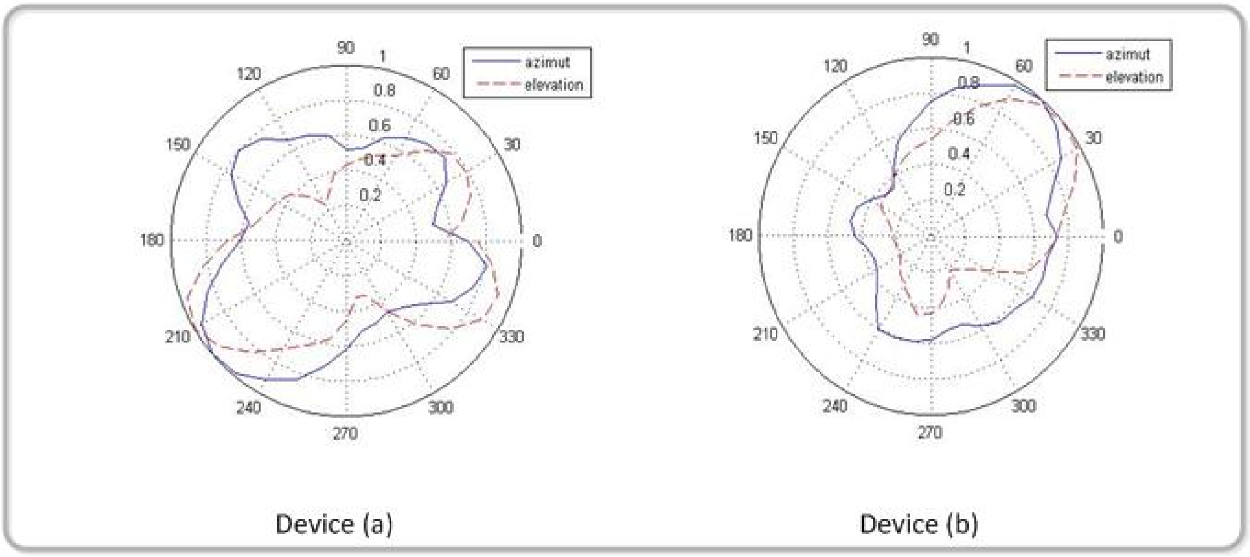

Figure 4. Radiation pattern of two models of social alarm devices: (a) AMIE+ Tunstall, and (b) Neat Atom.

FSM 016, with an HD10 controller to move it automatically. This positioning device is shown in Figure 5.

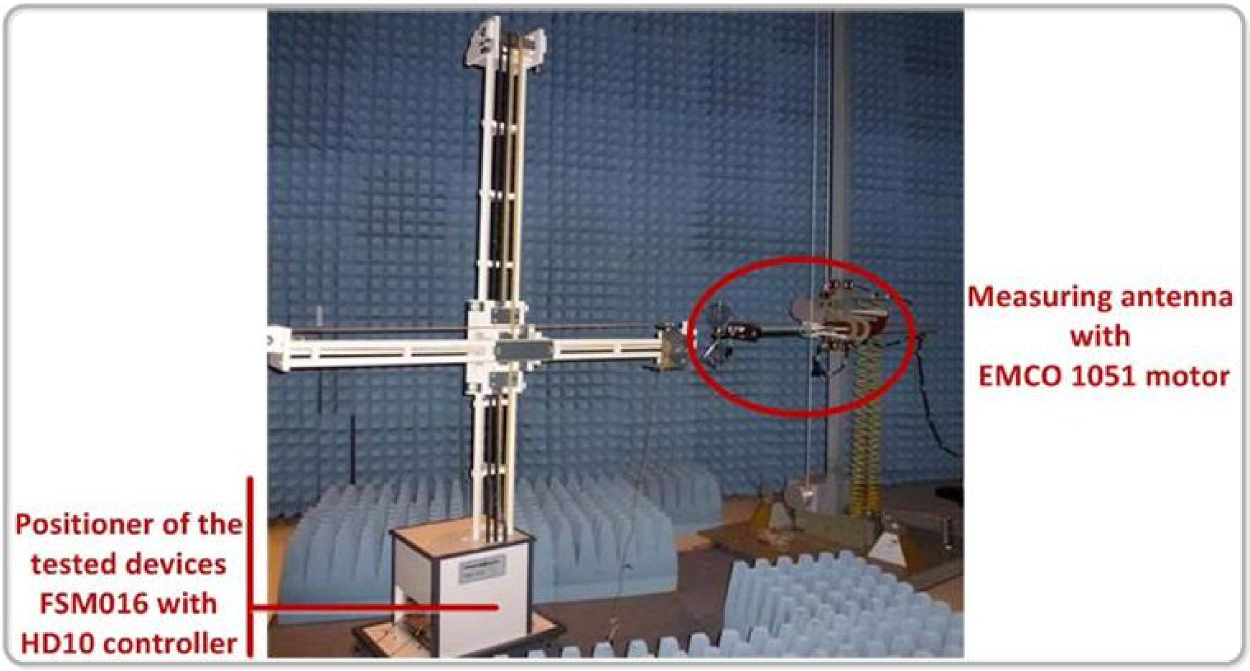

Figure 5. Measuring antenna and positioners required for the E-field measurements inside the anechoic chamber.

The measurements were carried out with an EMI Test Receiver ESIB26, Rhode & Schwartz with a frequency range of 20 Hz - 26.5 GHz. The EMI test receiver calculates the electric field strength taking into account the antenna factor and the cable attenuation, according to the following equation [16]:

$$E = V + AF + ATT \tag{1}$$

Where E is the electric field strength (dBuV/m), V is the measured voltage (dBuV), AF is the antenna factor (dBm^{-1}), and ATT is the cable attenuation (dB). After obtaining the horizontal and vertical components, the total field strength was calculated. The power density was derived using the following equation:

$$S = EH = \frac{E^2}{377} \tag{2}$$

Where the unit of S is W/m^2 and E has now been converted to linear units. The EIRP of each tested device was calculated for comparison with the emission limit of 16.4 mW set by standard regulations [15][17]. EIRP is the power that would have to be emitted if the antenna were isotropic in order to produce a power density equal to that observed in the direction of maximum gain of the actual antenna.

The EIRP is obtained from the power density as follows:

$$EIRP = 4\pi r^2 S_{\max} \tag{3}$$

Where EIRP is in units of W, r is the distance to the antenna in meters, and $S_{max}(r)$ is the maximum power density measured at each distance in W/m^2. The EIRP was calculated using the maximum measurement of power density, so the measurements of the electric field strength were realized in the direction of maximum radiation.

c. Compliance with exposure levels threshold

This research addresses the characterization of EM environments that are actually present in households, taking into account an analysis of the potential safe usage of domestic telemedicine systems. The data had been analysed with regard to potential risks and operational disturbances in accordance with existing European standards.

The field strength recorded from the tested devices have been compared with the corresponding International Commission on Non-ionizing Radiation Protection (ICNIRP) reference levels values defined for the general public depending on the working frequency [18].

It is also useful to compare the obtained levels with the thresholds for the safety and basic performance of the electromedical equipment. The International Electrotechnical Commission (IEC) Standard IEC 60601-1-2 [19], sets a minimum immunity level of 3 (V/m) for non-life supporting devices.

After calculating the parameters that characterize the emissions of the social alarm devices under testing, the results recorded are compared with the limit values set by the national and international bodies: Commission Implementing Decision of 8 December 2011 amending

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Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices (2011/829/EU) [15], and the Spanish National Table of Spectrum Location (ITC/332/2010) [17].

5. Results

a. Review of literature

Although most of the papers collected only partially cover the subject matter, the research performed for this chapter clearly demonstrates the high number of publications related to SRD in healthcare during recent years.

The number of papers seems to have increased significantly since 2001 as Figure 6 shows. The 248 papers finally included in our review were classified into six categories.

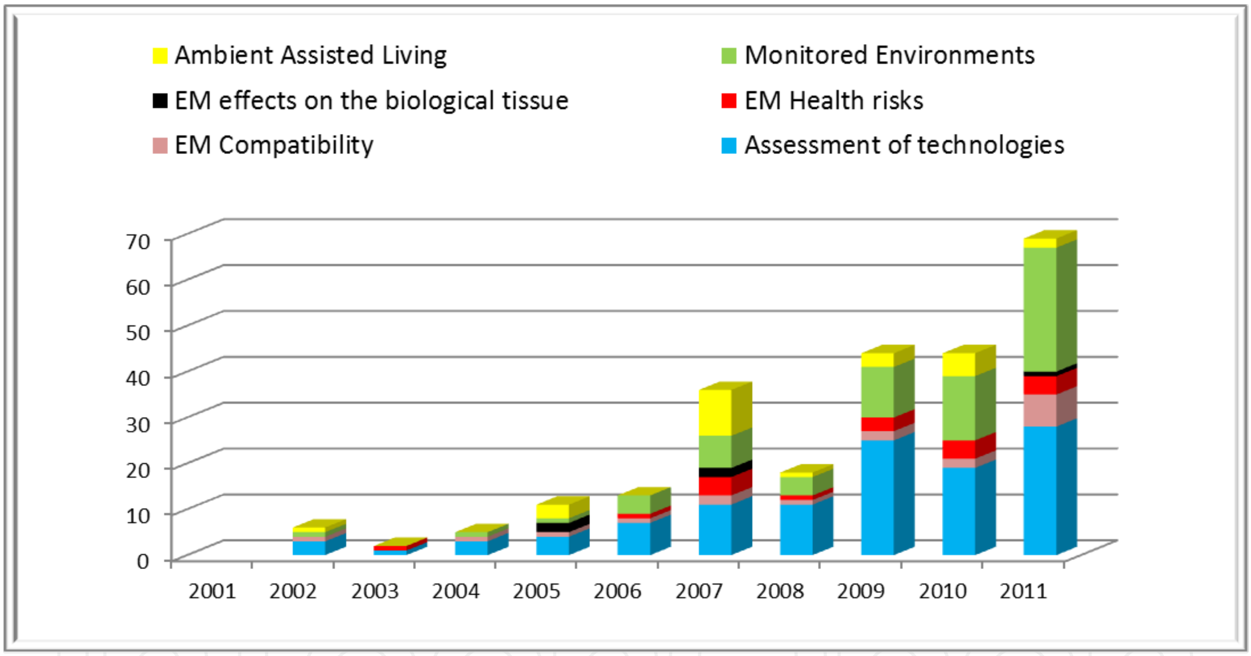


Figure 6. Papers which mention SRD technology in healthcare from 2001 to 2011 (Npapers: 248)

However, it is important to note the lack of publications which evaluate the effectiveness of SRD in real healthcare scenarios and most of the studies found only cover technological issues as is shown in Figure 7.

In this work, the two categories which are of most interest to the authors are AAL and monitored environments. Both characterize more complex scenarios, where SRD are combined with sensors to work together in a wireless network, finally connected to remote information repositories of data and software, as presented in Figure 1. Reducing hospital admissions and length of stay are main objectives in order to save economic and human resources, as well as to improve a patient's quality of life. However, most of these outpatients are elderly, or have

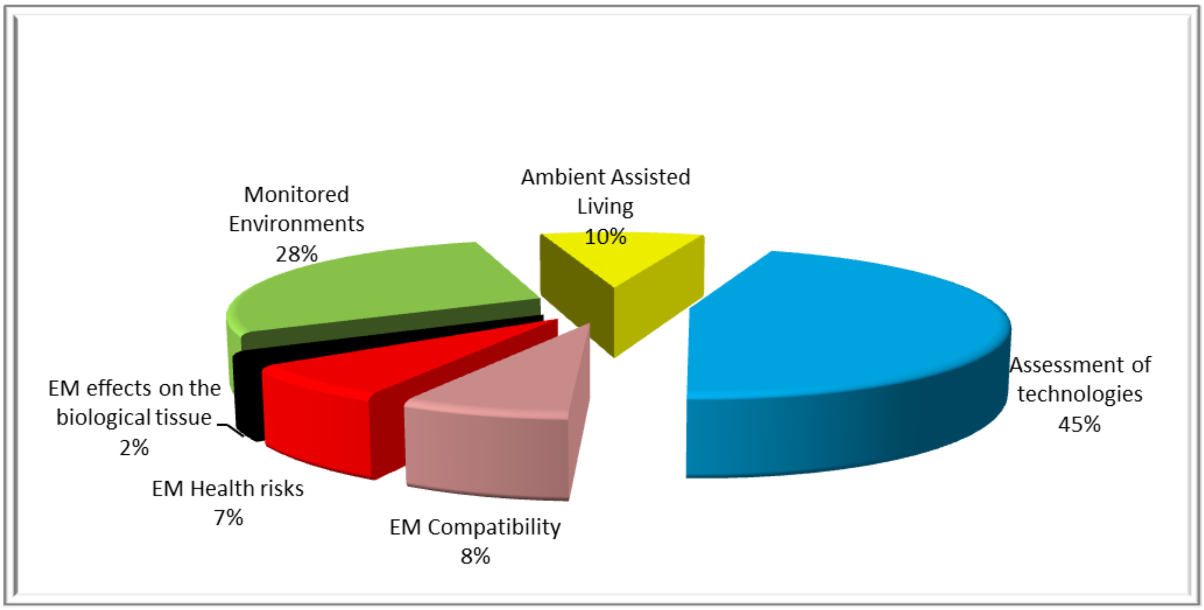
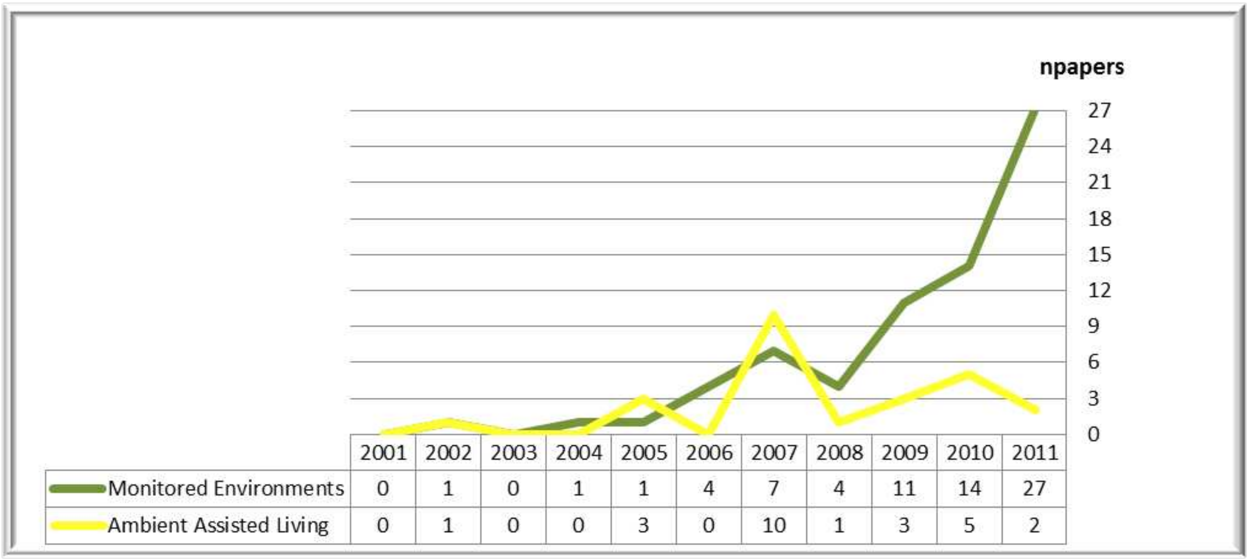


Figure 7. Applications Areas in terms of functionality (Npapers: 248)

a temporary or permanent disability, and many have no caregivers to help and technological advances can be very useful to fulfill that goal. From 2007, as shown in Figure 8, the number of papers dedicated to these two categories has been increased.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Monitored Environments	0	1	0	1	1	4	7	4	11	14	27
Ambient Assisted Living	0	1	0	0	3	0	10	1	3	5	2

Figure 8. Papers dedicated to AAL and monitored environments (Npapers: 95)

Figure 9 shows the different technologies that can provide useful help to patients, healthcare professionals, caregivers and families in emergent healthcare environments. There is a lack of published papers in the years 2001 and 2003.

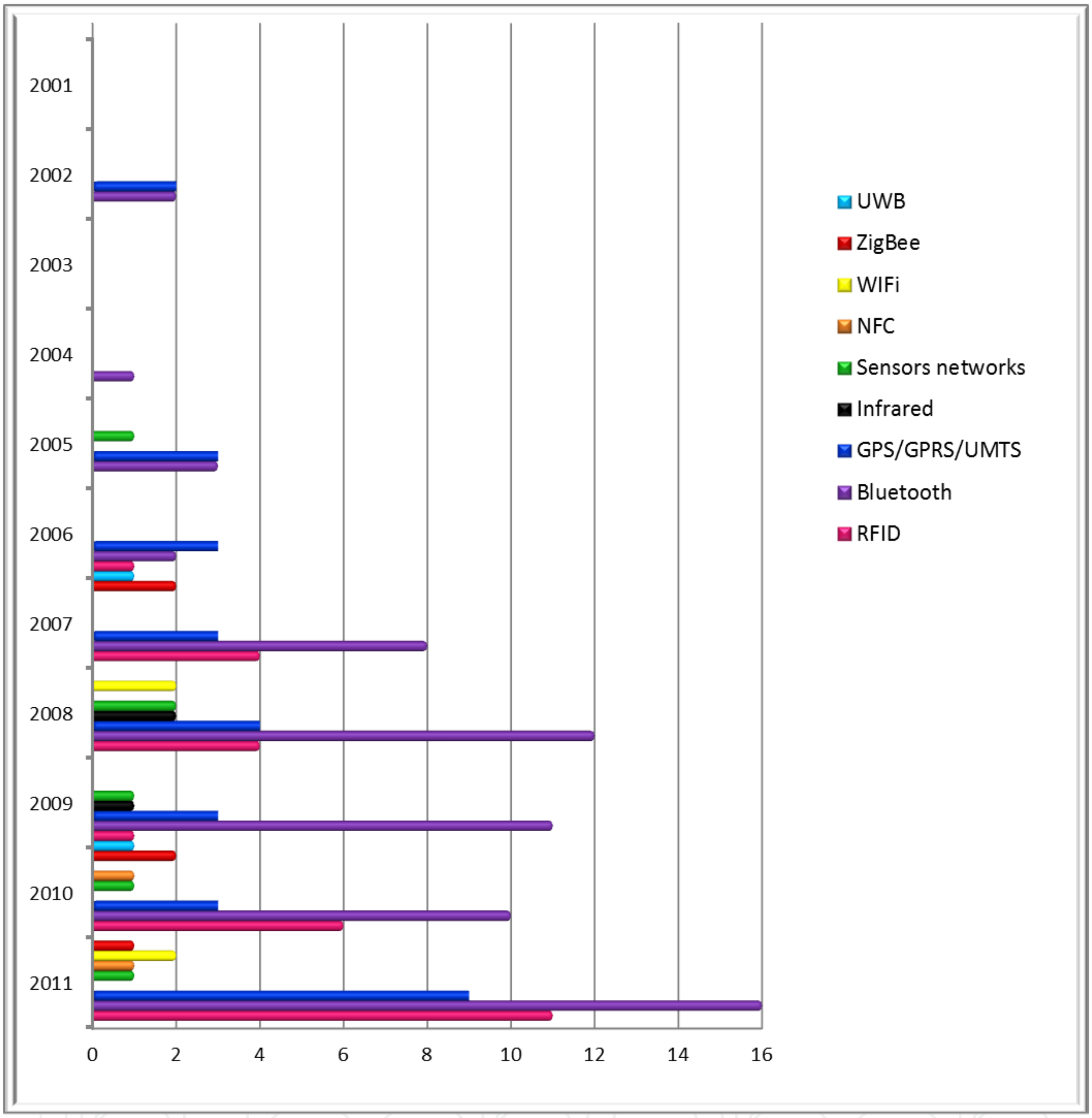


Figure 9. Technologies shown in papers for healthcare environments (Npapers: 95)

b. Measurements: electromagnetic laboratory evaluation

Different types of social alarm devices have been analyzed taking into account their emission features, the type of wireless technology, etc... This work presents a comparison of these systems in terms of their working conditions, and parameters that provide information about the emission levels.

Figure 10 shows the variation of the power density as a function of the distance for the tested devices operating at 869.21 MHz. The power density calculated from an EIRP equal to 16.4 mW limit is shown for comparison. The ordinate axis is represented in logarithmic scale to improve the comparison between the obtained results and the set limit of 16.4 mW. Overall, the power density plots calculated from maximum electric field strength as a function of distance broadly follow the expected inverse-square dependence on the distance.

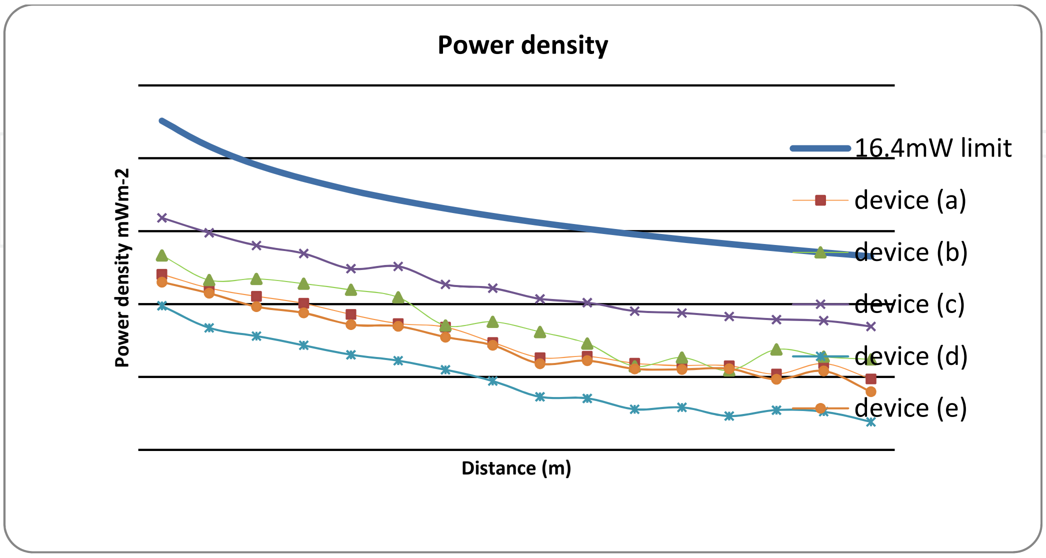


Figure 10. Variation of the power limit and the EIRP limit in function of distance for the five tested alarm devices: (a) AMIE+ Tunstall, (b) Neat Atom, (c) TX4 Bosch, (d) S37 TeleAlarm and (e) System 5000 Smart Call.

Table 2 shows the values of the maximum electric field strength (E), power density (S), and EIRP as a function of the distance, for two of the selected models of the social alarms devices, (a) AMIE+ Tunstall, and (b) Neat Atom.

c. Compliance with exposure levels threshold

ICNIRP guidelines contain reference levels expressed as values of the electric field strengths and power density that can be compared with measured or calculated values. All the field strengths recorded in this study are well below the corresponding ICNIRP reference level of 40 V/m defined for the general public at the working frequency (869.21 MHz) [18]. It means that electric field strength levels in healthcare home environments are apparently safe according to the health and safety requirements on the exposure of patients, professionals and the general public for protection against possible health effects from nonionizing radiation. The exposure levels thresholds stablished by the ICNIRP are shown in Figure 11.

The reference levels are not intended as limits, but are designed in such a way that complicance with them should ensure compliance with more fundamental basic restrictions.

One prominent concern to take into account is the possible interferences with medical devices. The IEC electromedical 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. This standard sets a minimum immunity level of 3 V/m for non-life supporting devices [19]. Examining the results, the maximum value of the electric field is much lower than the 3 V/m.

D(m)	E(mV/m)	S(mW/m²)	PIRE(mW)	E(mV/m)	S(mW/m²)	PIRE(mW)
	Device (a)			**Device (b)**		
0,2	310,662	0,256	0,129	419,038	0,466	0,234
0,3	249,879	0,166	0,187	283,527	0,213	0,241
0,4	219,518	0,128	0,257	289,373	0,222	0,447
0,5	196,383	0,102	0,321	267,815	0,190	0,598
0,6	164,764	0,072	0,326	243,292	0,157	0,710
0,7	142,712	0,054	0,333	215,788	0,124	0,761
0,8	134,910	0,048	0,388	138,447	0,051	0,409
0,9	105,952	0,030	0,303	146,854	0,057	0,582
	Device (a)			**Device (b)**		
D(m)	**E(mV/m)**	**S(mW/m²)**	**PIRE(mW)**	**E(mV/m)**	**S(mW/m²)**	**PIRE(mW)**
1	83,361	0,018	0,232	125,115	0,042	0,522
1,1	85,096	0,019	0,292	104,006	0,029	0,436
1,2	76,252	0,015	0,279	72,701	0,014	0,254
1,3	73,644	0,014	0,306	83,463	0,018	0,392
1,4	73,285	0,014	0,351	68,100	0,012	0,303
1,5	64,293	0,011	0,310	94,780	0,024	0,674
1,6	75,860	0,015	0,491	84,643	0,019	0,611
1,7	59,532	0,009	0,341	81,043	0,017	0,633

Table 2. Maximum electric field strength, power density, and EIRP for two models of the tested devices: (a) AMIE+ Tunstall, (b) Neat Atom

The recorded values of EIRP are well below the level that would be expected based on 16.4 mW, set by the national and international regulations: Commission Implementing Decision of 8 December 2011 amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices (2011/829/EU) [15], and the Spanish National Table of Spectrum Location (ITC/332/2010) [17], so the tested social alarm devices operate in safe conditions under the set limits of EIRP.

6. Discussions

This research identifies relevant studies which exemplify the penetration of SRD in new healthcare environments in real work flows. The evaluation of the methodological quality of studies has not been an easy task because of the heterogeneity of the papers included in the

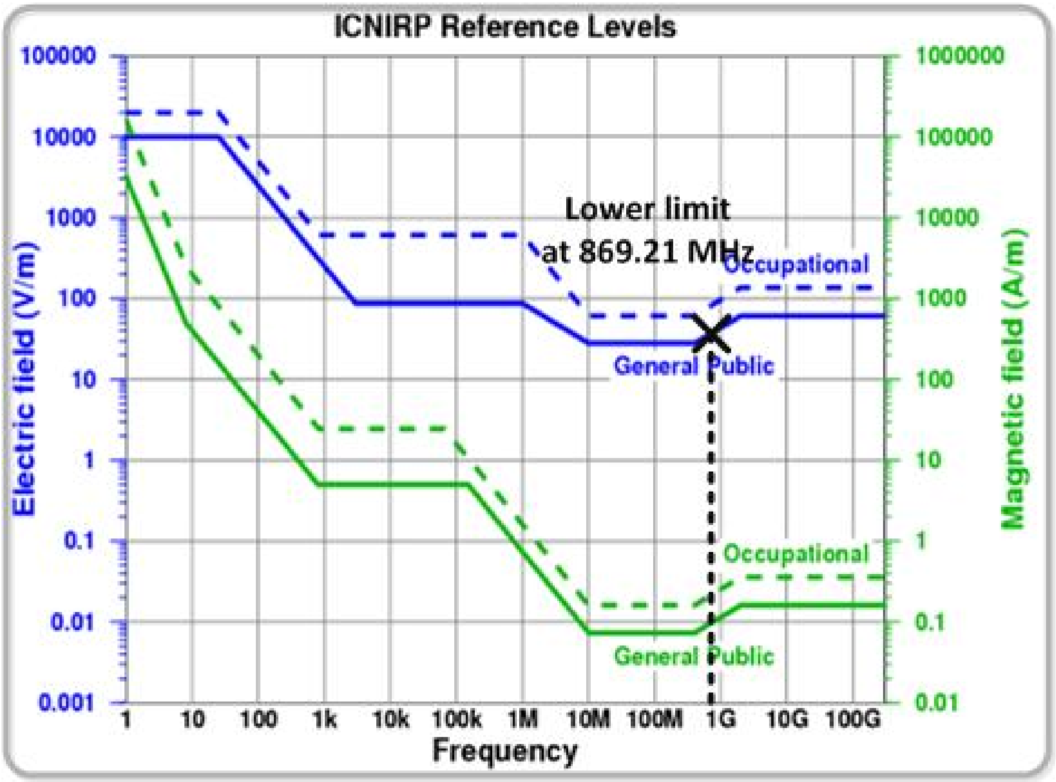


Figure 11. ICNIRP reference levels and the lower limit at working frequency of social alarm devices (869.21 MHz)

review. There are a lack of published papers in the years 2001 and 2003, as is shown in Figure 6. Most of the papers included only partially cover the subject matter.

The research performed for this chapter clearly demonstrates the high number of publications on technology assessments. However, despite the large number of studies found, there is a lack of publications evaluating effectiveness of SRD and most of the studies only cover technological assessment issues as can be observed in Figure 7. The absence of homogeneous criteria among authors to choose keywords to describe their papers may have an undesirable consequence: an indeterminate number of papers may have been omitted by search engines.

After reviewing the works it can be stated that wireless sensor nodes will play a key role in enabling the ubiquitous and proactive health monitoring and health care services of the future. To achieve the small form factors required, the reduction of node power consumption eliminates the need for large batteries and increases the energy autonomy of the node, hence reducing the amount of maintenance required. In this work several short range technologies for biomedical monitoring have been described in detail.

Future SRD and wireless sensor network applications in the health care domain are likely to require an even greater amount of data derived from a multitude of different sensors. The algorithms employed within these applications will become computationally more complex, resulting in a higher processing effort. Also, depending on the use of case scenarios, multi-sensory applications put higher demands on radio transmission. At the same time, the new care environments should operate on very small energy budgets, occasioanly using energy provided by harvesting devices alone, rendering power and energy-aware wireless sensor node design even more important. As well as this, the sensors need to be carried conveniently without disturbing the users' normal way of life: small in size, with low power consumption, and using wireless communications.

The fact that in the field of healthcare applications the most studied technology is Bluetooth, as shown in figure 9, and that the percentage of studies dedicated to the assessment of the technology is higher than any other, leads to an important lack of publications on EM risk exposure and EMC between wireless networks and medical equipment.

The use of SRD in assisted environments provides a lot of benefits and an important advance in the monitoring of patients and the elderly, improving the efficiency and the quality. But these successful factors may be accompanied by drawbacks if thresholds of exposure to electromagnetic fields are exceeded and if wireless networks cause degradation in electronic medical devices, which could potentially result in deaths, serious injuries, or administration of inappropriate treatment. The study of these critical successful factors can guide not only in the promotion, but also in the prevention in the use of SRD in healthcare applications. Therefore, the new implemented healthcare solutions must consider issues with respect to EMC and regulatory compliance.

Concretely, the conclusion of the analysis of Figure 7 and Figure 9 is that there are no previous studies about AAL and monitored environments based on social alarms devices operating at 869.21 MHz, and even less about the evaluation of the EMF levels in healthcare environments, despite the fact that these social alarm devices are very widely spread in the monitoring of daily activities of the elderly.

Therefore, one of the main objectives of this study is to quantify the exposure of people, and to analyse the compatibility between equipment and networks in monitored environments by social alarms devices. The electric field strength and the EIRP are well within the guidelines set by the ICNIRP, the IEC, and the thresholds set by standard regulations. It means that electric field strength levels in healthcare home environments are apparently safe according to the operational, health, and safety requirements on the exposure of patients, professionals and the general public for protection against possible health effects from nonionizing radiation.

Although one of the findings of this study is the development of an environmental study of the working conditions of the social alarm devices, it is also important to consider the absorption of radiofrequency energy in the body of a person that wears the device. ICNIRP guidelines are also expressed in terms of specific absorption rate (SAR), measured in W/Kg, in the body tissues. To address this, a parallel study should be carried out to measure the localized SAR arising from social alarm devices in the people that wear them.

7. Conclusion

On the whole, this chapter presents an overview of the current literature regarding the ratio of penetration as well as their real effectiveness. It provides physicists, patients and healthcare providers with information about parameters, effectiveness and the safety of SRD related to healthcare applications. The subject's content provides useful data for technology implementers in this growing field of AAL. Pervasive healthcare has been widely approved to be the next generation form of healthcare, in which distributed, patient-centric and self-managed care is emphasized compared to the more traditional hospitalized, staff-centric and professional managed care. The integration of SRD with other pervasive computing technologies such as communications protocols and wireless sensor networks is leading to further innovative applications in the telemedicine area, particularly for ubiquitous persistent monitoring of elderly or disabled people, as well as for patient follow-up during the rehabilitation phase where self-management of medication is prevalent. In recent years, many efforts have been made to develop contactless, portable sensors for continuous vital signs monitoring. But as of now, there are no standards for the system's size, architecture or performance.

Poor compliance for treatment, rehabilitation protocols and medication has become a well-known problem all over the world and causes worsening of disease, death and an increase in healthcare costs. In this context, AAL offers new possibilities to support outpatients in their daily routine to allow an independent and safe lifestyle without caregivers. The objects are capable of identifying, locating, sensing and connecting, and thus can lead to new forms of communication between people and things and things themselves. The development of real smart objects should be the next step, including ingestible or subcutaneous sensor tags.

These functional advantages can be overshadowed if the exposure thresholds are exceeded or if the use of SRD causes malfunction in other medical devices.

Given the increasing use of domiciliary telealarm devices, and the non-existence of previous studies about the working conditions and the emission levels, this paper analyzes two of the aspects that have to be considered to assure a proper, reliable and safe usage of social alarm devices operating at 869.21 MHz. The first is the compatibility with other communication networks and implanted electric devices. The second is the compliance with exposure levels threshold, to quantify and analyze the risk of exposure caused by the use of these devices.

After selecting the most widely used model devices, the emission levels were measured, saved, processed and analyzed to compare them with the existing standards. The obtained results show that electric field strength levels and the EIRP in healthcare home environments are apparently safe in terms of risk of exposure and EM compatibility.

The presented study provides a global, immediate and accurate vision that can help to avoid EM interferences, and monitor the exposure to EM fields of people using and in the proximity of social alarm devices in home environments.

New health solutions based on any kind of Short Range Technology must consider the issues of electromagnetic compatibility and regulatory compliance. Currently, the degree and type of EMF exposure need to be characterized in household settings, in order to ensure that applications operate properly and exposure guidelines are not exceeded.

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