Characterization of the Electromagnetic Environment in a Hospital: Measurement Procedures and Results

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Abstract:—"This paper investigates and describes the procedure to prepare and analyze the measurements necessary to describe and characterize the electromagnetic environment in a hospital in order to evaluate the conditions for failsafe operation for future Wireless Patient Monitoring. Measurement results are evaluated with respect to given immunity levels and in-band interferences. Results show that the UWB band features equal dynamic ranges as the ISM band but allows operation at a significantly lower power level, which is crucial for Wireless Patient Monitoring where low power consumption is highly required."

Introduction

Continuously monitoring patients in a hospital by electronic means is an indispensable tool, especially in intensive care. Up to now, wired sensors are used predominantly. Changing location, e.g. moving from surgery to anaesthetic recovery and further to intensive care, needs disconnecting sensors at the operating theater, connecting them to mobile equipment for transportation, and reconnecting them finally in intensive care. Wireless sensors would offer the possibility to dynamically reallocate monitoring equipment. This would significantly reduce the time and personnel needed for transporting patients, increase the accessibility for emergency treatment and also reduce the risk for the patient by avoiding interrupts in vital data monitoring. However, wireless sensors must cope with a harsh electromagnetic environment due to a myriad of different equipment generating electromagnetic fields within a hospital, like electrical cautery, paging systems and electrical power distribution networks. In order to specify the electromagnetic conditions for wireless patient monitoring sensors, the electromagnetic environment in a hospital must be characterized.

First efforts to characterize the electromagnetic environment in hospitals date back more than 30 years. In [1] the electromagnetic environment from 14 kHz up to 1 GHz of a hospital was assessed. In this paper, first emission limits for narrowband and broadband emissions are recommended for devices that are used in hospitals. In 1997, the first 'long term measurements' over a period of 24 hours showing temporal dependencies of the measured fields within a hospital for frequencies up to 1 GHz were described in [2]. Six years later the electromagnetic fields within the ISM band (2.4 GHz) were evaluated. The results are given in [3]. An extensive survey over the entire spectrum used by wireless communication services from 20 MHz to 10 GHz has not been carried out so far. Within the measurement campaign reported here, the maximum field levels used by telecommunication services are measured in order to account for 'worst-case' conditions. Measurement points are selected according to the different services present at the location and to expected emissions from specific medical equipment such as CT and MRI scanners, etc., and along typical patient transportation paths, that are higher electromagnetically burdened than others. Results are evaluated in regard to given immunity levels (EMC) and in-band interferences (EMI). The general approach and results of the measurement campaign were published in [4]. This paper here focuses on the procedure and the equipment used, but still includes the main measurement results.

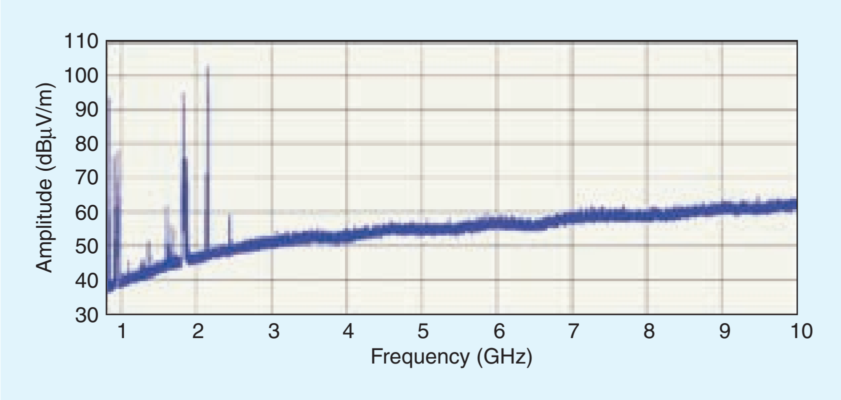

Fig. 1. Typical spectrum pattern in the hospital (800 MHz to 10 GHz).

Procedure, Equipment and Method

In order to identify areas of intense electromagnetic fields in the hospital, information about the location of wireless installations (e.g. broadcast stations) and location of special electrical equipment (e.g. CT-scanner) were collected. A good starting point is the database of the regulator, e.g. Swiss Federal Office of Communications (OFCOM), that contains information about installation locations of mobile phone base stations, broadcast stations and private mobile radio base stations. However, such a database covers only information about the location of outdoor installations and some indoor equipment. Therefore, the technical staff responsible for radio installations in the hospital needed to be contacted in order to get information about the location of different transmitting infrastructure together with the respective floor plans. Based on these information GSM micro cell stations, WLAN access points, DECT base stations, and paging transmitters could be located. Getting such information can be difficult because up to now, telecommunication infrastructure often grew organically in particular in a university environment, where new equipment is often installed for evaluation purposes.

Based on the collected information preliminary test measurements, using an EMF exposimeter (EME Spy 120, Antenessa SA), were undertaken. For this, the measurement device was carried in a daypack and the electromagnetic field levels were recorded at different corridors in the hospital. They were further used to identify interesting spots while walking through the hospital. The results showed a higher field variation for wireless services at crossing points of corridors due to the street canyon effect [5]. Hence we selected the crossing points as measurement locations in order to characterize field levels along typical transportation paths. Beside these measurement locations, so called 'hot spots' were picked, where higher field intensity was expected due to specific medical equipment such as CT and MRI scanners. Therefore, we conducted measurements in the emergency unit, operating theatre, neurocritical care unit, MRI- and CT-room and on the helipad. To locate 'hot spots', the spectrum monitor SRM3000 from Narda was used.

In order to account for location and time based field variations two different types of measurements were carried out:

1) *Stationary Short Term Measurements:* 'Stationary Short Term Measurements' were performed with a Rohde&Schwarz FSQ Spectrum Analyzer (SA) with different antennas from the HE-200 series (e.g. HE200-3000) and a Log-Periodic antenna (Grintek 470429-00000).

2) *Stationary Long Term Measurements:* For 'Stationary Long Term Measurements' the FSP SA from Rohde&Schwarz and a rod antenna was used which was directly connected to the SA. The SA was controlled by a macro to perform continuous measurements.

Table 1 summarizes the measurement equipment that was used during the measurement campaign. For the stationary measurements a period of 10 days were reserved. During this time at least three persons were necessary to carry out the measurements efficiently. Two were needed for performing the measurements (measuring, documentation), while a third person handled administrative work, such as informing hospital staff and answering questions from people walking by. Please note that the biggest effort does not only lie in the measurement process, but also in the organization and in receiving the required authorizations. Here the authorization of the hospital administration was required as a first step. In addition a special authorization of the physician in charge is needed to be able to perform measurements in sensitive areas, like in the emergency unit etc. Beside that the head nurses of the units must be also informed. Therefore it is highly recommended to establish contact with the special units at least four weeks prior to the planned measurements.

Measurement Method

The measurement methods are based on the recommendation of the Swiss Federal Office of Environment, Forests and Landscape [6], where general measurement principles (sweeping method)

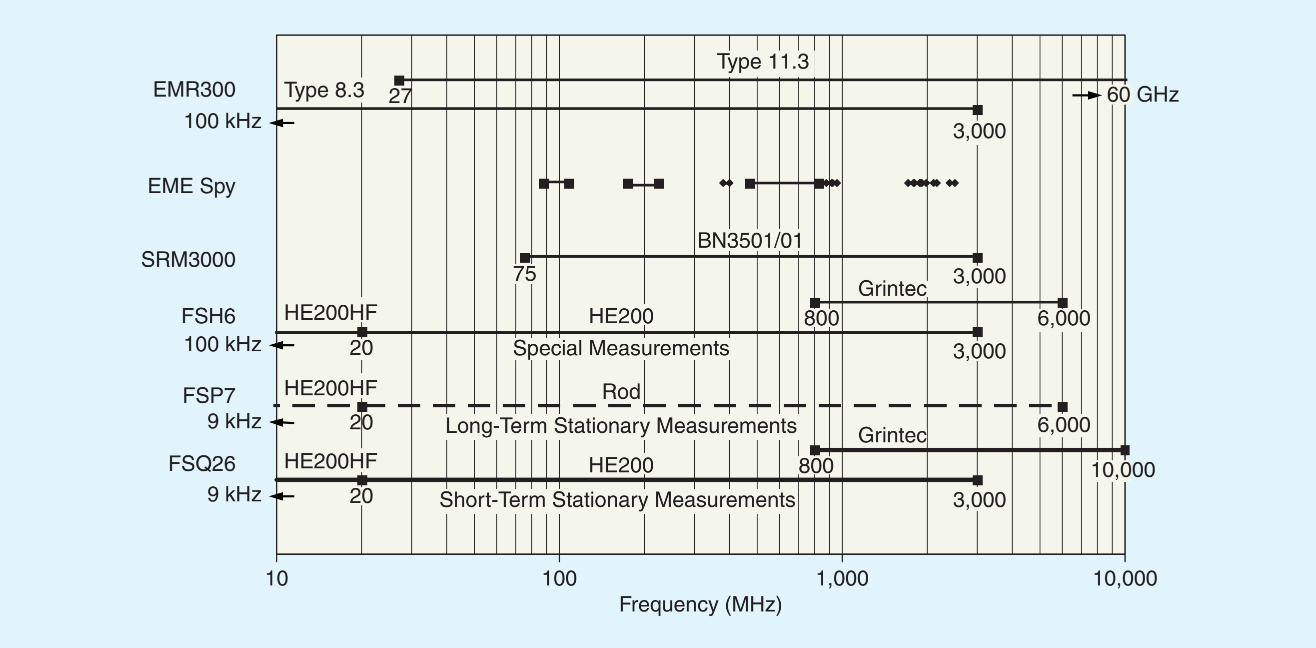

Table 1: Measurement equipment used: on the left side, the analyzing equipment is indicated. The horizontal lines show the frequency range with the respective sensor indicated above. The style of the lines indicates the type of measurements. 1. bold lines: short term stationary measurements 2. dashed lines: long term stationary measurements. 3. fine lines: special measurements.

and possible uncertainties are described. This report follows the approved measurement references of ANSI [7], [8]. As maximum levels of different services shall be assessed (EMC and EMI) we used 'Peak-Detector' instead of 'RMS-Detector' (RMS would refer to average electromagnetic exposure). For both measurement types the SA was set to 'Max-Hold' mode. Note that the measurement system was not pre-calibrated with antenna factors and cable attenuations, in order maximize the degrees of freedom to adjust and combine equipment parts during measurements.

At every measurement point the sweeping method was used within a space portion of an upright cylinder of 1 m diameter, beginning 0.5 m above the floor and up to 2 m.

Documentation of measurements is very important in order to clarify upcoming questions when analyzing the results. Therefore, distances from walls to measurement points were measured using a laser distance meter and pictures of the measurement area were taken.

Analysis

Measurement Uncertainty: The calculation of the measurement uncertainty is based on [9]. An example of an evaluation can be found in [10]. Data collection on the uncertainty of measurement equipment is demanding and requires the estimation of some parameters. Therefore, a more sophisticated approach than in [10] would be unreasonable. An uncertainty due to handling the equipment and different operator habits was introduced as applied in [11]. This value of ±30% uncertainty in reference to field strength within a confidence interval of 95% has been confirmed in round robin tests, e.g. [12]. Environmental uncertainty was not taken into account, because the intent was to indicate how good the measurements are in view of equipment and handling.

Measurements (expanded to a confidence interval of 95%) with the antennas HE200 and Grintec had an uncertainty around ±3 dB, with the 1 m long rod antenna (directly mounted to the analyzer) below ±4.5 dB. Care must be taken not to misinterpret measurement uncertainty: the values given here indicate the range where the absolute values may lay. However, relative deviations may be smaller during the measurement.

Determination of peak values: In a first step, the raw data values had to be calculated to field strengths, see Figure 1. Various combinations were possible between antennas, analyzers and cables. Therefore, each component of the measurement setup was characterized by a data sheet containing conversion, correction and attenuation factors in function of frequency. For each combination, a machine readable total conversion sheet was created. This allowed for automatic and identical processing of the raw data, avoiding processing errors.

The peak values of field strength were of main interest. In order to distinguish them from the noise, the mean value μ of the noise floor and the standard deviation σ was determined for different frequency bands. Based on these calculations a threshold value is determined as four times the standard deviation of system noise plus mean value of the noise

$$E_{j > \mu_i} + 4\sigma_i \tag{1}$$

Using a threshold value with four times the standard deviation, includes more than 99% of the noise distribution, and thus allows for a better separation between radio signals and noise. In a next step peaks bigger than threshold value E_j are extracted (see Figure 2) and further evaluated.

Results

Stationary Short-Term Measurements: Figure 3 summarizes the peaks occurring at all measurement points within the frequency range from 800 MHz–10 GHz. Accumulation of peaks occur around typical radio services like GSM900, GSM1800 and DECT reaching maximum field strengths up to 122 dBµV/m. Further peaks occur within the ISM-band at 2.4 GHz and for Local Area Networks (LAN) at 5.3 GHz achieving maximum field strength of 118 dBµV/m and 106 dBµV/m respectively. Within the UWB regions from 3.1–5.3 GHz and 5.4–10 GHz levels are in the range from 70 dBµV/m to 60 dBµV/m.

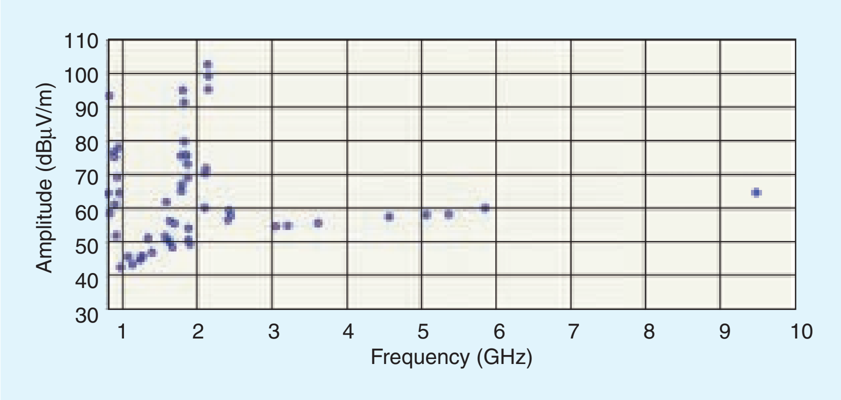

Fig. 2. Extracted peaks from the spectrum pattern (800 MHz to 10 GHz).

Below 800 MHz, most frequencies are already occupied. The fields encountered are important in terms of the immunity issues mostly. Especially the paging systems are responsible for 'hot spots' with up to some V/m (see Figure 4). In other hospitals, broadcasting might contribute more significantly to the overall emissions.

Figure 5 shows the measured field levels below 20 MHz. The peaks and noise observed are caused often by electrical transportation cars, chargers or computer network cabling.

Beside these results for stationary short term measurements the following further observations were made:

- Many DECT signals were noted, therefore, an extra scan in the frequency range from 1.8 up to 1.9 GHz containing DECT as well as GSM1800 downlink, was conducted.
- Some infrared warming equipment was found that emitted fields even when "switched off". Some special transportation equipment was emitting fields when being charged in standby.
- The fields of the emergency diesel backup generators during a maintenance check were measured: no special signals were found.
- Automatic telling machines can cause EMC problems, but nothing special was encountered.
- Some stray radar motion detectors for door openers at 9 GHz were still radiating, but not always anymore connected to the doors.
- Transportation equipment (bed movers, electrical cars) and cleaning cars seem to emit substantial fields below 20 MHz.
- Outside fields can be quite high due to mobile communication stations that are often located around hospitals because of the quite high amount of phone traffic created by hospital visitors.
- Computer tomography and small MRI were not showing especially high fields. Even the RF fields outside a 7 Tesla MRI were moderate with the access doors closed.
- The wireless microphone systems in an auditorium created substantial fields.
- Bedside equipment towers and infusion towers in intensive care (treating towers) are emitting electromagnetic fields, too: especially infusion pumps.

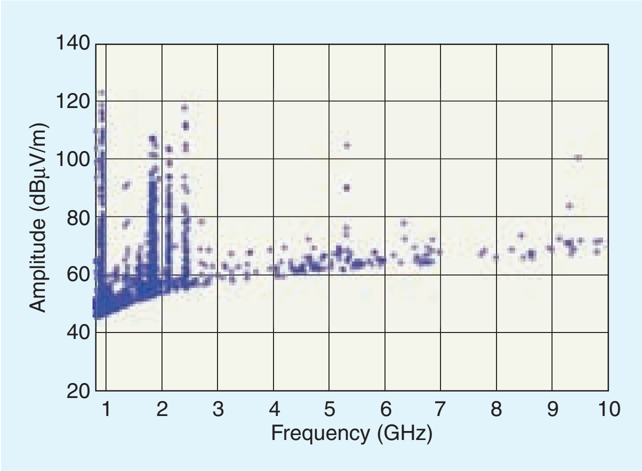

Fig. 3. collection of the peaks of all short term stationary measurements with FSQ26/Grintec (800 MHz to 10 GHz).

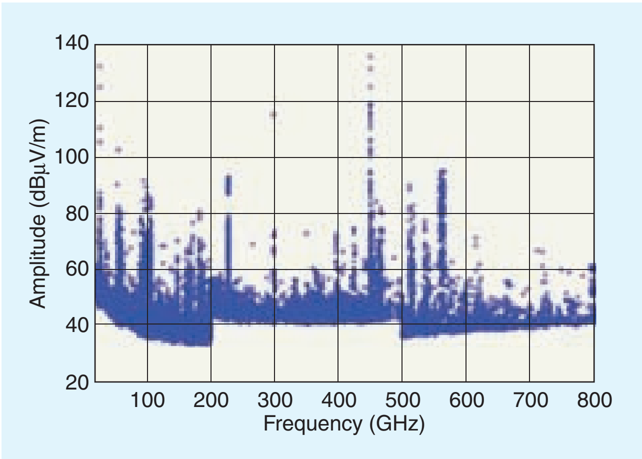

Fig. 4. Collection of the peaks of all short term stationary measurements with FSQ26/HE200 (20 MHz to 800 MHz).

Stationary Long-Term Measurements:

To ensure that infrequent high peaks are not missed by stationary short term measurements, stationary long term measurements were performed.

For 'long term measurements' the neurocritical care unit, the emergency room and one operating theater of neurosurgery were selected, because higher field levels can be expected due to the numerous electrical appliances that are in use, see [13].

Figure 6 and Figure 7 show the time dependent field variation for the GSM900 uplink and the PPS II band (Public Paging System) over a period of 24 hours.

For analysis, the deviation of each detected peak to the statistical mean value over 24 hours was calculated for different

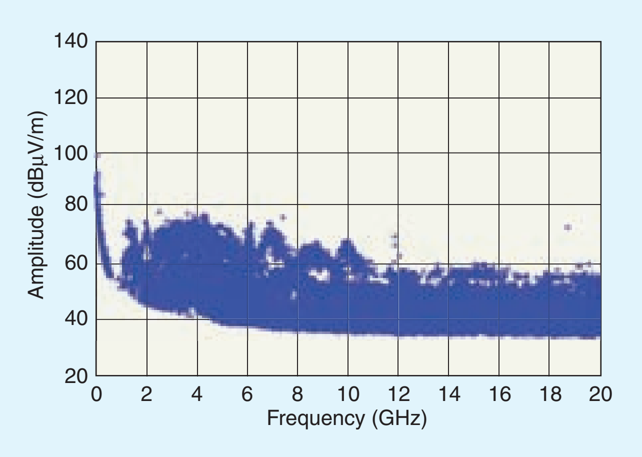

Fig. 5. Collection of the peaks of all short term stationary measurements with FSQ26/HE200HF (9 kHz to 20 MHz, not at all measurement points).

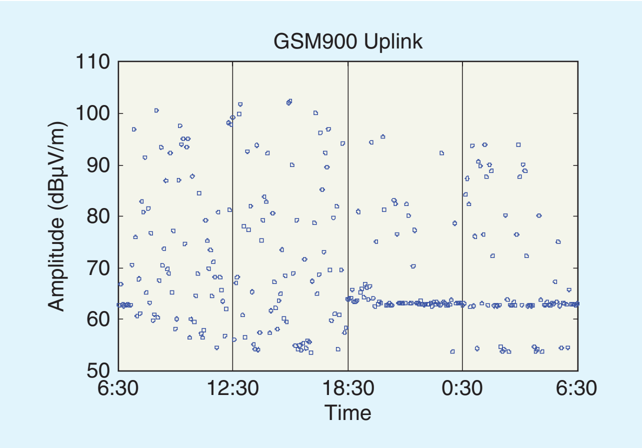

Fig. 6. Collection of the peaks over 24 hours for GSM900 uplinks recorded in the intensive care unit with FSP7/rod antenna (20 MHz to 6 GHz).

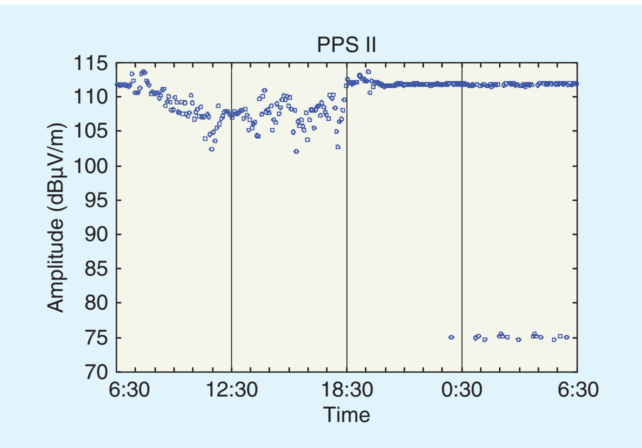

Fig. 7. Collection of the peaks over 24 hours for the 450 MHz paging system recorded in the intensive care unit with FSP7/rod antenna (20 MHz to 6 GHz).

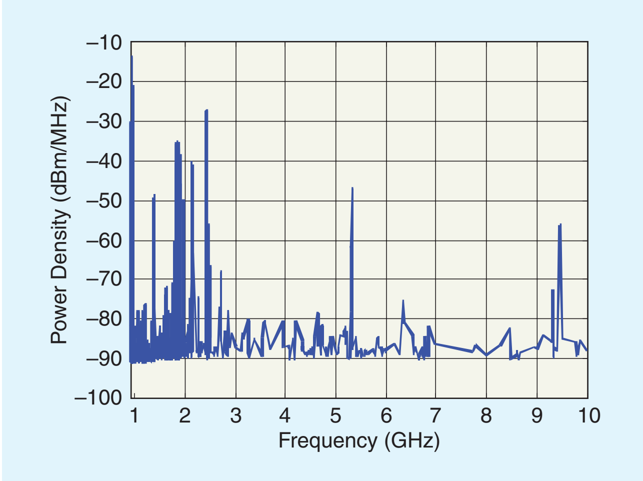

Fig. 8. Calculated received noise power density for an isotropic antenna.

services. If the average deviation stays below the measurement uncertainty of the measurement setup, a short term measurement would then be sufficient. The results show a big temporal variability for all long term measurement locations for GSM handsets (see Figure 6), UMTS and DECT. Most of the services feature maximum peaks during breakfast and lunch time. The averaged deviation for GSM 900 uplink was calculated to 13 dB. UMTS base station signals showed a similar variability. This can be explained by the high dynamics of the power control for UMTS.

Within the emergency room, we also observed a higher deviation for three additional services, namely DAB, Tetrapol and PPS II (450 MHz). This can be explained by significant changes of the environmental conditions of the highly shielded emergency room during the frequently open doors. These services feature a much higher field deviation than the measurement uncertainty of the short term measurement setup ($\pm$3.3 dB). Hence it is highly recommended to perform long term measurements in order to record maximum occurred peaks. On the other hand there are locations (e.g. neurocritical care unit) where the services like the personal paging system (450 MHz) feature an average deviation that stays below the measurement uncertainty (see Figure 7). Here short term measurements are sufficient to record maximum peaks.

The International Electrotechnical Commission (IEC) specified an immunity level of 3 V/m = 129.5 dBµV/m to prevent electronics in medical devices from interferences [14]. This limit was exceeded in one case for PPS I and in two cases for PPS II. The cumulative contribution of multiple sources operating within regulations in different frequency bands can easily lead to a field level >3 V/m at some locations. The worst case measured fields at one point constructively sums up to a field level of 3.4 V/m, which was measured on a corridor in the main building. This suggests that the evaluation of the cumulative maximum field levels is required in order to ensure compliance with current immunity levels defined for medical devices.

Based on the maximum peaks that were measured between 900 MHz–10 GHz the received noise power density is calculated for an isotropic receiving antenna with no reflection and polarization losses, see Fig. 8. The maximum Pulse Spectrum Density (PSD) is −28 dBm/MHz for wireless applications using the ISM band like Bluetooth, ZigBee and WLAN. In contrast one can find different frequency ranges having a much lower power density with a maximum value of −81 dBm/MHz, e.g. in the UWB band from 3.1 to 5.3 GHz. Based on the measured transmission PSD of different technologies and the measured interference power density, the Signal to Interference Ratio (SIR) can be determined and compared. The SIR reflects directly the reliability of the communication link. For systems based on duty cycle schemes such as Impulse Radio UWB, the SIR can be traded off against lower pulse repetition rate (PRR) to reduce power consumption. A comparable system to UWB in terms of communication distance is the Bluetooth (BT) class 2 with a transmission power density of $S_{t,max}$ = 4 dBm/MHz. In the further analysis, interference avoiding schemes such as frequency hopping are neglected. For BT this leads to a SIR of

$$SIR_{BT} = 4 \text{ dBm/MHz} - (-28 \text{ dBm/MHz}) = 32 \text{ dB/MHz}. \quad (2)$$

Compared to a UWB system with $S_{t,max} = -41.3$ dBm/MHz, we have

$$\begin{aligned} SIR_{UWB} &= -41.3 \text{ dBm/MHz} - (L_{nfs} - 81 \text{ dBm/MHz}) \\ &= 36.7 \text{ dB/MHz}, \end{aligned} \quad (3)$$

where L_{nfs} = 3 dB is the implementation loss due to the non optimal frequency occupancy of the UWB spectral mask when using Gaussian pulses. These results show that UWB features a slightly better dynamic range but at much smaller power levels. Furthermore it can be expected that the impact of the simultaneous operation of many UWB devices for Wireless Patient Monitoring (WPM) has only little effect on SIR_{UWB} throughout the hospital, because of the smaller transmission power and hence the limited range. Thus SIR_{UWB} is only affected locally and a high spectral reuse is possible with the full dynamic range of 36.7 dB/MHz.

Outlook

The data collected might be further analyzed with respect to wireless services, locations and time. Further mobile measurements are planned, where the electromagnetic fields will be recorded assuming a person is being transported along a typical transportation path in the hospital. This can be realized by putting the measurement setup into a bed that is moved along a typical transportation track. This way, a better view of the changes of fields, when a patient is transported, could be obtained, especially how significantly a metal structure moving through the corridors is altering the environmental fields. To have a closer look at electrical transportation means is intended, too. Also spot measurements at a non medical office and inside a normal private home would be interesting for comparison. RFID readers might be an issue as well [14]. Further very long term measurements (some weeks) at the helipad could give an additional view on field variations.

Conclusion

This report shows an extensive survey of the electromagnetic environment from 9 kHz up to 10 GHz in the university hospital in Zurich. Furthermore the procedure, equipment and method for performing measurements in a hospital environment is described. Two different types of measurement were carried out in order to record worst-case time- and location-based characteristics. Measurement uncertainties have been evaluated to be ±3.3 dB for 'stationary short term measurements' and ±4.3 dB for 'stationary long term measurements'.

In some cases the immunity level specified by the IEC was exceeded. The EM interference sums up to 3.4 V/m for a worst case scenario where all the maximum field levels from all different services added up at one measurement point. For such a case the immunity level does not provide adequate protection of electric devices. The evaluation of the cumulative maximum field levels is required in order to ensure fail-safe operation for worst-case conditions, and to be compliant with current immunity levels defined for medical devices.

The results allow the determination of the link dynamic range of different wireless technologies which are potentially suited for short range applications like sensor networks. Based on the measured field levels the received power density for an isotropic antenna was calculated between 900 MHz and 10 GHz.

The results show that UWB features a slightly better dynamic range but at much smaller power levels. Furthermore it can be expected that the impact of the simultaneous operation of many UWB devices for WPM has only little effect on SIR_{UWB} throughout the hospital, because of the smaller transmission power and hence the limited range. Thus SIR_{UWB} is only affected locally and a high spectral reuse is possible with the full dynamic range.

Good preparation and organization are of major importance, especially because measurements must be conducted in a running hospital, otherwise the signals would not be realistic. Finally, we hope that other groups can profit from our experiences and conduct similar measurements in other hospitals or other professional locations.

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References

[1] U. A. Frank and R. Lodner, "The hospital electromagnetic interfernce environment," *Journal of the association for advancement of medical instrumentation*, vol. 5, no. 4, pp. 246–254, 1971.

[2] P. Vlach, C. Liu-Hinz, B. Segal, and T. Pavlasek, "The electromagnetic environment due to portable sources in a typical hospital room," *IEEE 17th Annual Engineering in Medicine and Biology Society Conference*, vol. 1, pp. 683–684, 1995.

[3] S. Krishnamoorthy, J. Reed, C. Anderson, M. Robert, and S. Srikanteswara, "Characterization of the 2.4 GHz ISM band electromagnetic interference in a hospital environment," *IEEE 25th Annual Int. Conf. on Engineering in Medicine and Biology*, vol. 4, pp. 3245–3248, 2003.

[4] O. Lauer, M. Riederer et al, "Characterization of the electromagnetic environment in a hospital," *Electromagnetic Compatibility and 19th International Zurich Symposium on Electromagnetic Compatibility, 2008. APEMC 2008. Asia-Pacific Symposium on*, 2008, S. 474–477.

[5] R. Janaswamy, *Radiowave propagation and smart antennas for wireless communication*. Kluwer Academic Publishers, 2001.

[6] Bundesamt für Umwelt Wald und Landschaft. (1992, May) Messung nichtionisierender elektromagnetischen Strahlung. [Online]. Available: http://www.bafu.admin.ch/php/modules/shop/files/pdf/phpfWggLm.pdf
[7] American National Standards Institute (ANSI), "Recommended practice for the measuremente of hazardous electromagnetic fields – RF and Microwave," The Institute of Electrical and Electronic Engineers, Tech. Rep., 1981.
[8] —, "Recommended practice for the measuremente of hazardous electromagnetic fields – RF and Microwave," The Institute of Electrical and Electronic Engineers, Tech. Rep.,
[9] ISO and IEC, *Guide to the expression of uncertainty in measurement*, ISO, 1993.
[10]CENELEC, "EN 50492, Basic standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations," 2008.
[11]BUWAL, Sektion NiS und METAS, Sektion Hochfrequenz, EMV und Verkehr, "Mobilfunk-Basisstationen (GSM), Messempfehlung," 2003; http://www.bafu.admin.ch/php/modules/shop/files/pdf/php-k0Yt1Z.pdf.
[12] Federal Office of Metrology METAS, "Measurement of non ionizing radiation from a broadcasting station: An Inter-laboratory Comparison," Autumn. 2007.
[13]R. M. Nelson, H. Ji, "Electric and magnetic fields created by electrosurgical units," Transactions on electromagnetic compatibility, Vol. 41, No. 1, pp. 55–64, 1999
[14]R. van der Togt et al, "Electromagnetic Interference From Radio Frequency dentification Inducing Potentially Hazardous Incidents in Critical Care Medical Equipment," *JAMA*, vol. 299, Juni. 2008, S. 2884–2890.

Biographies

Markus Riederer *was born 1960 in Basel, Switzerland. He received his M.Sc. in Electrotechnical Engineering from ETH Zürich in 1985.*

In 1983, from 1986 to 1987, and from 1989 to 1992, he was responsible for projecting, operating and maintaining various radio networks in crisis, disaster and remote areas. From 1987 to 1989 he was charged with type approval of sound and TV broadcast transmitters within the Swiss PTT. There, he advised additionally in theoretical questions of environmental EMC (NIR: Non-Ionizing Radiation) regarding broadcasting. He was involved in compatibility studies of the ITU between aircraft communications and broadcast. In 1993, he joined OFCOM (Swiss Federal Office of Communications) where he was involved in conformity assessment with later concentration in the fields of GSM, satellite, and microwave communications. In addition, he conducted NIR expertises. In 2000, he changed within OFCOM to the EMC/NIR group where he is working on calculation and measurement methods regarding NIR for cellular mobile radio, satellite and microwave systems and EMC interference problems. In 2002, the technical part of the GSM-measurement campaign in Salzburg was directed by him. He participates in the development of NIR measurement standards: be it nationally (GSM, UMTS) or internationally in CENELEC and IEC. Since 2005, he chairs the Swiss National Committee IEC/CENELEC TK106 "Human Exposure to Electromagnetic Fields."

Oliver Lauer *received the Dipl. Ing. in electrical engineering in W'06 from the University of Karlsruhe, Germany. He is currently working toward the PhD degree with ETH Zurich, Switzerland in the Laboratory for Electromagnetic Fields and Microwave Electronics.*

His research interests include EMC measurements, EMC modeling and system simulations.

Rüdiger Vahldieck *(M'85–SM'86–F'99) received the Dipl.-Ing. and Dr.-Ing. degrees in electrical engineering from the University of Bremen, Bremen, Germany, in 1980 and 1983, respectively. He was a Postdoctoral Fellow with the University of Ottawa, Ottawa, ON, Canada, until 1986. In 1986, he joined the Department of Electrical and Computer Engineering, University of Victoria, Victoria, BC, Canada, where he became a Full Professor in 1991. During Fall and Spring 1992–1993, he was a Visiting Scientist with the Ferdinand-Braun-Insitute für Hochfrequenztechnik, Berlin, Germany. In 1997, he became a Professor of electromagnetic field theory with the Swiss Federal Institute of Technology, Zurich, Switzerland, and became Head of the Laboratory for Electromagnetic Fields and Microwave Electronics (IFH) in 2003. In 2005, he became President of the Research Foundation for Mobile Communications and was elected Head of the Department of Information Technology and Electrical Engineering (D-ITET), ETH Zurich. Since 1981, he has authored or coauthored over 300 technical papers in books, journals, and conferences. His research interests include computational electromagnetics in the general area of EMC, and in particular, for computer-aided design of microwave, millimeter-wave, and opto-electronic integrated circuits.*

Jürg Fröblich*, born 1964, received his Diploma in Electrical Engineering and his PhD from the Swiss Federal Institute of Technology Zurich. In 1998 he joined the Institute of Operations Research at the University of Zurich where he developed a Simulation Platform for Multistage Stochastic Programming Problems. In 2000 he joined the Foundation for Research on Information Technologies in Society (IT'IS), Zurich as a Projectleader for Computational Tools and Risk Assessment. In May 2004 he was promoted to Associate Director of IT'IS. Since November 2005 he is leading the Group for Electromagnetics in Medicine and Biology at the Laboratory for Electromagnetic Fields and Microwave Electronics, ETH Zurich. His research activities cover Computational Tools for Electromagnetics, Applications of Electromagnetics in Medicine and Biology and Technology and Risk Assessment of wireless technologies. He is a member of the Swiss TC106X on Electromagnetic Fields in the Human Environment and of the working group 1 on EMF Monitoring and Measurement of the new COST Action BM0704. He also acts as an expert for Electromagnetic Fields in the Human Environment for ANEC, the consumers voice in standardization, funded by the EU and EFTA.*

EMC