TNO Quality of Life

Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek / Netherlands Organisation for Applied Scientific Research

Prevention and Health
Wassenaarseweg 56
P.O. Box 2215
2301 CE Leiden
The Netherlands

www.tno.nl

T +31 88 866 90 00
F +31 88 866 06 10
info-zorg@tno.nl

TNO report

KvL/P&Z2010

93 Medical Apparatuses tested at a Hospital for interference by WLAN/WiFi signals

Date December 2010, corrected

Author(s) R. Hensbroek, M.Sc.

Number of pages 49 (incl. appendices)
Number of appendices 4

Summary

This research describes the influence of WLAN [1)] signals on medical apparatuses in a Hospital. The results in this report were obtained by testing medical equipment with WLAN signals. A comparable research was reported in 2007: See TNO report KvL/P&Z 2007.117 dated September 2007, **Literature** [**1**].

At 15cm distance 3% of 93 tested medical apparatuses were disturbed. At 0cm distance (WLAN antenna against medical apparatus) 4% of the apparatuses were disturbed. The WLAN signals were transmitted at 100mW, which is the standardised power in the 2,4 and 5GHz frequency bands. The character of all (of the 4% of 93) found interferences was unsafe for the patient; the maximum distance at which interference was found was 150cm.

These results are comparable to the results in the TNO study from 2007 – The 3% border now at the present hospital (15cm) is somewhat bigger than the border in 2007 (10cm). Another small difference is the maximum distance where interference occurred: 150cm now versus 50cm in 2007.

The number of medical apparatuses tested (93) can be considered large enough to formulate the following general expectation: As long as the distance between WLAN antennas and medical apparatuses is more than 20cm during normal use in hospitals, hardly interferences and/or unsafe disturbances are expected. At shorter distances in special situations disturbances are expected.

Attention for this interference aspect is important if non medical apparatus (e.g. PDA's) with WLAN antennas are (in normal use) placed on medical apparatus, or if WLAN antennas are built into medical apparatuses that are placed on top of or under other medical apparatuses. In these cases the distance can be 0cm and some disturbances are expected. Testing and special measures may be needed to prevent this.

During this research signals were transmitted at the extra strong power level of 500mW as well. This was done to facilitate finding possible disturbances more quickly than normal. These results are not included in the conclusions mentioned above because WLAN systems will not be used at that strong power level in hospitals. No patients were involved in the research; where necessary, input signals for the medical apparatuses were generated with simulators. The medical apparatuses were set up fully functional. They were powered from the mains and in some cases from built-in accumulators.

Remarks

1: The test method minimized dependency from the environment where the tests took place.

2: If in this report for a certain type of medical apparatus no interference is reported, the conclusion that the apparatus is not susceptible is not warranted because tests were limited, had a typical (restricted) purpose and were not intended to cover the standard IEC 60601-1-2 [**4**] for EMC of Medical Equipment. A conclusion about

[1)] WLAN = Wireless Local Area Network (In Dutch Language: Draadloos lokaal netwerk), also called WiFi = Wireless Fidelity.

the complete EMC behaviour of a medical apparatus is the responsibility of the manufacturer and must be based on more elaborate testing.

3: The number of medical apparatuses included in the immunity testing was limited. The medical apparatuses were carefully selected to cover the actual situation in the rooms at the hospital. The medical apparatuses and the WLAN systems are believed to represent a collection as can be found in more hospitals. No strict general conclusions about other medical apparatuses can be drawn from this report without careful judgment and comparison. In case of doubt additional testing may be needed (as international standards advise generally as well).

Samenvatting

Dit rapport beschrijft de invloed van WLAN [2)] signalen op medische apparaten in een ziekenhuis. De resultaten in dit rapport zijn verkregen door medische apparatuur te testen met WLAN-signalen. Een vergelijkbaar onderzoek is in 2007 gepubliceerd: Zie TNO report KvL/P&Z 2007.117 dd. september 2007, **Literature** [**1**].

Op 15cm afstand trad bij 3% van 93 onderzochte medische apparaten storende invloed op. Op 0cm afstand (WLAN antenne tegen medisch apparaat) ondervond 4% van de apparaten storing. De WLAN signalen hadden het gebruikelijke vermogen van 100mW in de 2,4 en 5GHz frequentiebanden. Het karakter van alle (4% van 93) gevonden storingen was onveilig voor de patiënt; de maximale afstand waarop storende invloed werd gevonden was 150cm.

Deze resultaten zijn vergelijkbaar met de resultaten in de TNO studie uit 2007 – De 3% grens bij het huidige ziekenhuis (15cm) is wat groter dan de grens uit 2007 (10cm). Een ander klein verschil is de grootste afstand waarbij interferentie optrad: 150cm bij het huidige ziekenhuis tegen 50cm in 2007.

Het aantal onderzochte medische apparaten (93) kan groot genoeg worden geacht om de volgende algemene verwachtingen uit te spreken: Zolang WLAN antennes op meer dan 20cm afstand van medische apparaten blijven tijdens normaal gebruik in ziekenhuizen zijn nauwelijks storende en/of onveilige invloeden te verwachten. Op kortere afstand zullen in bijzondere gevallen storingen kunnen optreden.

Aandacht voor deze stoorproblematiek is belangrijk wanneer niet medische apparaten (bijvoorbeeld PDA's) met WLAN antennes op medische apparaten worden gebruikt, of wanneer WLAN antennes worden ingebouwd in medische apparaten, die op of onder andere medische apparaten "gestapeld" kunnen worden. In deze gevallen kan de afstand 0cm worden en zijn soms storingen te verwachten. Testen en het nemen van speciale maatregelen kunnen nodig zijn om dit te voorkomen.

Bij het onderzoek werd ook met de "bovennormale" sterkte van 500mW gezonden om gemakkelijker eventuele storingen op het spoor te komen. Die resultaten zijn niet in bovenstaande conclusies meegenomen, want WLAN systemen zullen niet op die sterkte in ziekenhuizen worden bedreven. Bij het onderzoek waren geen patiënten betrokken; er werd waar nodig gewerkt met simulatoren die de ingangssignalen leverden aan de medische apparatuur. De medische apparatuur was volledig functioneel opgesteld en werd gevoed vanuit het net en in sommige gevallen uit de ingebouwde batterij.

Opmerkingen

1: De testmethode minimaliseerde de afhankelijkheid van de omgeving waar de test plaats vond.

2: Wanneer in dit rapport van een bepaald apparaat geen verstoring wordt gemeld mag daar niet de conclusie aan worden verbonden, dat dit apparaat dus niet gevoelig is. Het apparaat is immers slechts beperkt getest en met een zeer bepaald (beperkt) doel. De norm IEC 60601-1-2, **Literature [4]**, voor EMC van medische apparatuur

[2)] WLAN = Wireless Local Area Network (Draadloos lokaal netwerk), ook wel aangeduid met WiFi = Wireless Fidelity.

was zeker niet afgedekt. Een dergelijke uitspraak behoort tot de competentie en verantwoordelijkheid van de fabrikant van het betreffende apparaat en moet worden gestoeld op uitvoeriger onderzoek.

3: Het aantal onderzochte medische apparaten was beperkt. De apparaten zijn zorgvuldig geselecteerd met het oog op de toepassingssituaties in ziekenhuizen. Zowel de medische apparaten als WLAN systemen kunnen als representatief worden beschouwd voor meerdere ziekenhuizen. Echter, er kunnen geen strikte algemene conclusies voor andere medische apparaten worden gebaseerd op dit rapport zonder zorgvuldige beoordeling en vergelijking. In geval van twijfel kan het nodig zijn om aanvullend te testen (zoals internationale normen in het algemeen ook adviseren).

Contents

1 Introduction

This research describes the influence of WLAN signals on medical apparatus in a hospital. The results in this report were obtained by testing medical equipment with WLAN signals. A selection of the medical equipment of the hospital was tested for susceptibility to these signals. This report describes the tests and presents the results. These results are formulated in such a way that the hospital can base management strategies and/or technical measures on them to consider introduction of WLAN systems. The aim was to test whether selected medical apparatuses (see below) were susceptible to WLAN signals and if so at what distance. The character of possible reactions (hazardous or not) was also of interest.

1.1 Description of tests

In order to test possible susceptibility of medical apparatuses, 93 of them were set upon their own in the hospital environment and subjected to the WLAN signals. Medical apparatuses were selected that could in principle be positioned in the vicinity of the WLAN antennas [3]) during normal functioning of the intensive care unit, the operating room, etc. Where relevant, the medical apparatuses were tested both powered from the mains and powered from their internal accumulator. If a medical apparatus was found that could be disturbed, the point in space furthest away from the medical apparatus was determined where interference starts. This is the separation distance **d**. The name indicates that possible sources of WLAN signals should be kept away from this medical apparatus more than this “separation distance”. At a found disturbance position, transmission of the WLAN signal was realized during several tens of seconds (typically 30 seconds). Testing was done according to a predefined testing program with predefined WLAN test signals. In the next paragraphs the following is presented:

- The chosen medical apparatuses tested;
- The choice and generation of the WLAN test signals;
- The way interference testing was performed;
- The test results and their interpretation (tables with descriptions of disturbances found at specified distance).

[3]) Not the antennas of Access Points (A.P.s) of installed WLAN systems were considered relevant in this study. On the contrary: As relevant were considered: The antennas of hand-held devices with which users may move around medical apparatus. (In WLAN terminology these hand-held devices are called “clients”). In this study the antennas of these hand-held devices were “simulated” by using Access Points.

2 Choice of Medical Apparatuses tested

When selecting medical apparatuses to be tested the key criterion was the direct medical safety for the patient at locations in the hospital. Some selected laboratory instruments are considered “medical apparatus” as well in this report.

In Table 2.1 below it is presented how many medical apparatuses of a certain type were tested at the hospital within the total of **93** tested medical apparatuses. Within one type / model / function of medical apparatus, more than one make was tested in a number of cases; never the same type / model was tested twice; no research was done on the variations within one type / model. As the last column indicates **17** medical apparatuses were tested that were connected to a medical apparatus that was tested as well. These connected apparatuses were tested and reported as separate apparatuses in this study.

Table 2.1: Type and number of medical apparatuses tested.

Medical apparatuses tested (Type)	Number of medical apparatuses tested	Number of medical apparatuses connected
Ventilator	5	
Syringe Pump	2	
Volumetric Infusion Pump	1	
Monitor/Meter	8	
Ultrasound Diagnostic Scanner	1	
Dialysis	1	1 (No. 8b)
EKG	1	
External Defibrillator / Monitor	1	
Neonatal (infant) Incubator	1	
Infant Warmer	2	
Fluid Warmer	1	
Hypohyperthermia	1	
Cell Saver	1	
Surgical Navigation	2	
Heart Lung Machine	1	
Heater/Cooler	1	
Insufflator	3	
Electrosurgery	1	
RF Lesion Generator (Pain Management)	1	
RF Generator for Endovenous Ablation	1	
Laser	4	
Bone densitometer	1	
Mammography/Biopsy	2	
Bucky room	2	9 (No. 32 b-e and 33 b-f)
X-Ray Chest system	1	
Stereotaxis system	1	
Cardiac Stimulator (EP)	1	
Angiographic contrast Injector	1	
Pacemaker Programmer	3	
Breath Analysis	1	

Medical apparatuses tested (Type)	Number of medical apparatuses tested	Number of medical apparatuses connected
UV-B cabin	1	
IR – Spectral Photometer (Laboratory Pharmacy)	1	
Medicine Analyser (Laboratory Pharmacy)	1	
Microplate Reader (Laboratory Pharmacy)	1	
Mass Spectrometer (Laboratory Pharmacy)	1	
Automated Hematology Analyzer	1	3 (No. 57 b-d)
Blood Glucose Meter	1	
Blood Gas Meter / Analyser	2	
Clinical Chemistry System (Dep. HKCL)	1	3 (No. 60 b-d)
Microbalance	2	
Handheld Contamination Monitor	1	
Radiation Monitor	1	
Radiation Dose Kalibrator	1	1 (no. 74 b)
Quality Control System	1	
Well Meter (Put Kristal)	1	
Chromatogram Scanner	1	
Hand/Foot Radiation Contamination Detector	1	
Endoscope drying cabinet	1	
Endoscope washer / disinfector	1	
RF wireless sensorsystem (Lab Microbiology)	1	
Oxygen Detection	1	
Total 93 =	76 +	17

In **Chapter 5** of this report the medical apparatuses tested are specified further. In **Appendix A** more details are given.

The following categories of apparatus were deliberately not included in the tests:

- Medical apparatus not likely used near the WLAN antennas such as implantable pacemakers or hearing aids;
- Electric wheelchairs;
- Medical equipment used at home;
- Most non medical apparatus.

Medical apparatuses were tested according to a protocol that was settled before testing. Medical apparatuses were tested in normal use modes.

3 WLAN Test signals

Three WLAN systems were tested for their possible interfering influence on medical apparatuses. The selection of the WLAN systems was an essential part of the testing process. The WLAN systems had different signal characteristics as can be seen from Table 3.1 below. As can be seen from the table, the carrier frequencies of the WLAN systems were 2,4GHz and 5GHz respectively.

The test signals of the WLAN systems are summarized in the next paragraphs. The test signals were chosen with the intention to have included in the testing as many normally used signals from WLAN systems as possible. WLAN signals can differ strongly depending on carrier frequency, data rate, package size and transmission conditions. All test signals fulfilled the international standard IEEE 802.11X with X being a, b or g. The presently upcoming system "n" can be considered to be included in the tests because from interference point of view on the radio communication channel "n" has the same power and frequency characteristics as a, b and g [4)]. As indicated in Table 3.1, the power level of some test signals was increased to 500mW. For the final conclusions in this report only the results at 100mW were used.

Table 3.1 Summary of the WLAN signals used for interference testing.

802.11.X	Frequency	Data rates **)	Channel	Power [mW] *)
X = b	b: 2,4GHz	b: 11Mbit/s	b: Ch1	b: 100mW
X = a + g	g: 2,4GHz	g: 54Mbit/s	g:Ch11	g: 100mW or 500mW
	a: 5GHz	a: 54Mbit/s	a: Ch36 and: a: Ch64	a: 500mW, provided with an extra amplifier a: 100mW

*) The output power at the antenna connector was set in such a way that the power radiated from the antenna was at the level indicated in this column (EIRP). For the final conclusions in this report only the results with 100mW were counted and results with higher power were neglected.

) Possible data rates for 802.11 **b are: 1, 2, 5.5 or 11Mbit/s according to the standard. Possible data rates for 802.11 **g** and **a** are: 6, 12, 24, 32 or 54Mbit/s.

To summarize the table above: During testing the following test signals were available:

- Ch1 (100mW/2,4GHz/11Mbit/s);
- Ch11 (500mW/2,4GHz/54Mbit/s) could also be switched to 100mW;
- Ch36 (500mW/5GHz/54Mbit/s);
- Ch64 (100mW/5GHz/54Mbit/s).

Depending on the package size the WLAN signal has different "zero-periods" on the radio connection: periods in which the Access Point (A.P.) is "listening". At the data

[4]) We omit that at 5GHz the allowed power is 200mW (ETSI EN 301 893 v.1.5.1 dd. 2008-12). We tested at 100mW because all manufacturers specify 100mW for in-house applications of their access points. For information we also tested at 500mW.

link layer the signal was filled up with packages: short, middle or long packages (in bytes). At the PC the packages could be changed during the testing sessions:

- Short packages (length: 80 bytes),
- Middle length packages (length: 600 bytes),
- Long packages, (length: 1400 bytes)

On a digital oscilloscope signals were registered as typical samples of test signals on time scale of 0,1ms/div., 1ms/div. and 10ms/div. (see photograph in **Appendix C**).

At the hospital only long packages were transmitted because from earlier tests it revealed that long packages resulted in most interference (worst case).

Channels 1, 11, 36 and 64 were used in the testing. These channels are the most outer channels in the two frequency bands (2,4GHz Band and 5GHz Band) as far as indoor use is concerned. In the European Union Channel 13 may be used as well. This channel was not used for the interference tests. Not using this Channel was considered not influencing the relevancy of the results of the interference tests for the European situation – even when Channel 13 would be used. The reason for this being not relevant is that from EMC point of view the frequencies of Channel 11 and 13 hardly differ.

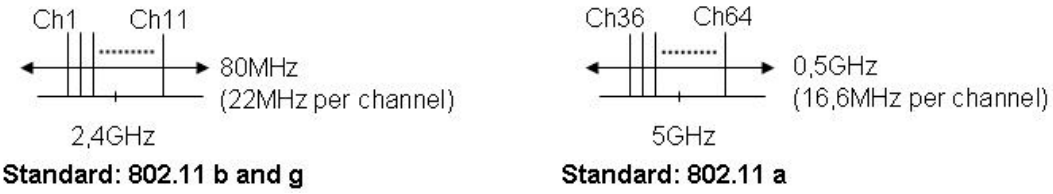


Figure 3.1 Channels 1, 11, 36 and 64 in their respective frequency bands at 2,4GHz and 5GHz according to the IEEE 802.11 standards.

The routine testing practice on every testing day was as shown in Table 3.2.

Table 3.2 Overview of routine testing practices.

Testing order	
1	Switch off GSM phones.
2	Every test set-up in a new environment and every new day: - Make a spectrum registry of WLAN test signals as proof that test signals / field strength had the correct amplitude.
3	Have the medical apparatus functioning at normal settings. Simulate patient input signals or organize a volunteering test person to simulate patient signals (e.g. ECG).
4	Test with all transmitting antennas around the medical apparatus at the same time: - Testing duration: several tens of seconds (=typically 30s). - Start at 0cm from the medical apparatus, - Move around the medical apparatus with the Access Points
5	If disturbance occurs: find the separation distance **d** = biggest distance at which disturbance occurs.

Details of the test set-up can be found in **Appendix B** to this report.

4 Test Protocol

Interference tests were performed at several departments of the hospital: IC, OR, Laboratory, etc. Test locations facilitated enough space around the medical apparatuses (typically 2m). Before testing started it was verified that at locations around, under and above the testing location, no interference issues could arise in the hospital practice. The test practices as described below were followed.

Test practices
The medical apparatus was positioned in such a way that it could be radiated from all sides (no persons or objects in the direct surroundings of the apparatus - especially not a metal testing table – unless this table was the permanent location of the medical apparatus). Medical apparatuses were functioning normally; patient simulator or test person and/or patient phantom connected; attention was paid to possible sensitivity of simulators. For ECG apparatuses an ECG simulator was used or a volunteering testing person connected. For ventilators an artificial lung was used. The point in space was searched, most far from the apparatus, where it could just be disturbed. When testing for possible susceptibility at a certain position in space, transmission was realized during several seconds. At a found disturbance position, transmission was realized during several tens of seconds before reporting.
The reaction of the medical apparatus (if any) was noted down: flashing lamps, audible alarms, display disturbances, all details. When the apparatus stopped, it was also reported whether it could be restarted by switching it OFF and ON again and whether all settings were lost or not. When disturbances occurred, it was also checked whether memory functions were disturbed.

Some typical test situations can be seen in the photographs in **Appendix C** to this report.

Remarks
1: The test method minimized dependency from the environment where the tests took place.
2: If in this report for a certain type of medical apparatus no interference is reported, the conclusion that the apparatus is not susceptible is not warranted because tests were limited, had a typical (restricted) purpose and were not intended to cover the standard IEC 60601-1-2 **[4]** for EMC of Medical Equipment. A conclusion about the complete EMC behaviour of a medical apparatus is the responsibility of the manufacturer and must be based on more elaborate testing.
3: The number of medical apparatuses included in the immunity testing was limited. The medical apparatuses were carefully selected to cover the actual situation in the rooms at the hospital. The medical apparatuses and the WLAN systems are believed to represent a collection as can be found in more hospitals. No strict general conclusions about other medical apparatuses can be drawn from this report without careful judgment and comparison. In case of doubt additional testing may be needed (as international standards advise generally as well).

5 Results

5.1 Introduction

In **Paragraph 5.3** below the results of interference tests are presented in detail. At first in **Paragraph 5.2** a possible classification of disturbances is presented. In **Paragraph 5.4** the results are summarized and in **Paragraph 5.5** presented graphically. In **Paragraph 5.6** the results are compared to interference by GSM phones.

5.2 Classification of disturbances

Disturbances and/or interferences at the medical apparatuses were classified according to Table 5.1 below. The classifications only apply to the interference at the specific apparatus. The classification **U** (**U**nsafe) is not restricted to life threatening situations for the patient. The importance of interference must be seen in the right perspective: in a way every disturbance is unacceptable during treatment of patients [5)].

Table 5.1: Classification of disturbances/interferences in medical apparatus.

	Meaning	Example
N	**No**, no disturbance or interference occurs	- Irrelevant noise or rumble from a loudspeaker.
L	**Light** disturbance occurs	- Small interference on the Video Display/Screen of a medical apparatus but no disturbance of the functioning of the apparatus. - Relevant noise or rumble from a loudspeaker.
S	**Significant** but not (yet) unsafe disturbance	- Disturbance of the functioning of the apparatus but no safety hazard for patient or user - no indirect safety hazard as well. - Small “spikes” on ECG curves. - Disturbances on a display without hazard.
U	**Unsafe** disturbance	- Defibrillator with “spikes” on ECG curves (synchronisation error) - (Correct) failure messages without acoustical alarm. - Disturbance or stopping of an apparatus without (acoustical) alarm. - Disturbing a process or an indication (example: a display) with a safety hazard aspect.

[5)] The standard IEC TR 60513 **Literature [8]** lays down the international safety philosophy for medical apparatus. In this standard the starting point is the “vulnerable patient” who often is restricted partially or totally in reflex actions, using sense organs, movability, alertness, etc. Therefore the safety philosophy for medical apparatus is totally different from the safety philosophy for household or industrial equipment for example, that is used by healthy persons being not patients.

5.3 Detailed results

In this paragraph all tested medical apparatuses are tabulated and all found interferences / disturbances are described in detail. The results are presented for the 100mW and the 500mW signals separately.

In total 93 apparatuses were tested at the hospital in June and July 2010. Nearly all were medical apparatuses or laboratory apparatuses (exceptions: an RF radio sensor system and an oxygen level alarm system).

The numbering of the medical apparatuses reflects the order of testing which was determined by practical circumstances like availability of a specific apparatus.

In table 5.2 below the separation distance **d** [in cm] can be found in column 4 named **Interference Y/N**. The separation distance **d** was determined for both 100mW and 500mW transmitted power. If interference was found, the WLAN Channel (1/ 11/ 36/ 64) is specified in the column 5 in table 5.1. Details about WLAN Channels can be found in chapter 3 of this report.

Legend to Table 5.2 below
Column 1: The **No. in test** refers to the testing order of the medical apparatuses as recorded during the interference testing. Some photos which illustrate the testing method can be found in **Appendix C** to this report.
Column 2: Medical apparatus tested are presented in this column per functional group. The type (name) of each medical apparatus is mentioned as it was indicated on the apparatus itself followed by the name of the manufacturer. The functional mode during testing of each apparatus is described in **Appendix A**. Seventeen medical apparatuses were connected to medical apparatuses tested. They were tested as medical apparatuses as well.
Column 3: The Year of purchase by the hospital. In cases marked with "?" the year of purchase could not be found or there was doubt about it.
Column 4: In this column the separation distance **d** is given for those medical apparatuses that were influenced by WLAN signal(s). The letter **N** means that no interference occurred at any distance from the medical apparatus including distance 0cm (=WLAN antenna against the medical apparatus). The footnotes in columns 4 refer to details of the interferences found. In columns 4 the influences found are classified according to the **N/L/S/U** scheme [6] as described in **Paragraph 5.2** of this report.
Column 5: The channel that transmitted the WLAN signal in case of interference.

6) **N**/**L**/**S**/**U** = **N**o/**L**ight/**S**ignificant/**U**nsafe disturbance or interference. In Netherlands language: = **N**/**L**/**S**/**O** = **N**ee/**L**ichte/**S**ignificante/**O**nveilige verstoring of interferentie.

Table 5.2 Overview of all tested medical apparatuses and description of all interferences found, the separation distance d per apparatus and the classification (N/L/S/U) of the interference.

No. in test	Medical apparatus tested	Year of purchase	Interference Y/N Classific. N/L/S/U 100mW: …cm 500mW: …cm	Channel No. 1/ 11/ 36/ 64
	Ventilator			
4	Savina (Transport Ventilator), Dräger	10	N	
36	Bipap Knight Star 335, Nellcor Puritan Bennett	00	N	
37	Bipap Harmony, Respironics, Inc.	10	N	
42	Babaylog 2000, Dräger In transport Incubator 5400 together with No. 43	04	N	
66	Leoni 2 Neonatal ventilator, Heinen und Löwenstein (Accutronic)	10	N	
	Syringe Pump			
2	Argus 600 Green Stream SY-P, Argus Medical	05	N	
12	Orchestra NL Module DPS, Fresenius Vial Tested in Orchestra Base Primea	04	N	
	Volumetric Infusion Pump			
20	Model 598, Ivac	03	**Y [7] Classific.: U 100mW: 20cm 500mW: 30cm**	 **11** **11**
	Monitor/Meter			
18	Patient Monitor Intellivue MP5, Philips	09	N	
1	Patient Monitor MP70 (Intellivue M8007A),Philips	09	N	
38	FMS Flexible Module Server, Philips; Tested with MP70 (No, 1)	04	N	
17	ST Analysis: STAN S31 Fetal Heart Monitor, Neoventa Medical AB	07	N	
21	ST Analysis: STAN S21 Fetal Heart Monitor, Neoventa Medical AB	04	N	
19	Fetal Monitor Viridia Series 50XM, M1350B, Hewlett Packard	99	N	
43	Oxygen Monitor MaxO2, Ceramatec In transport Incubator 5400 together with No. 42	97	N	
69	Cardiac Output Meter Vigilant Vig 2E, Edwards **Restricted test (no measurements on screen)**	09	**N** [8]	

[7]) **Ch11** 500mW: 30cm from right side: Acoustic alarm + Error message on screen: P7.
Ch11 at 100mW: 20cm from right side: Acoustic alarm + Error message on screen: E n.
The pump could not be brought back to normal functioning: the error message stayed on. However, after four (4) hours (another pump: 24 hours) the error message disappeared and the pump could be used again. The hospital personnel recognized this error behaviour as occurring already several years (gsm?).

[8]) Restricted test due to failing test features: Only temperature indication was active; no curves on screen; no cardiac output measurement was running.

No. in test	Medical apparatus tested	Year of purchase	Interference Y/N Classific. N/L/S/U 100mW: …cm 500mW: …cm	Channel No. 1/ 11/ 36/ 64
	Ultrasound Diagnostic Scanner			
30	Xario XG, Toshiba; Tested with probe 12L5	09	N	
	Dialysis			
8	5008 Fresenius Medical care	07	N	
8b	Aqua Uno Reverse Osmosis, Fresenius Medical care; Tested with 5008 (No 8)	08	N	
	EKG			
50	Electrofysiologic System Labsystem Pro, C.R. Bard, Inc. Incl.: 2 Monitors in HCK, 2 Monitors + PC on Desk, EKG-amplifier, IC Module	00	N	
	External Defibrillator / Monitor			
5	Heartstart MRx M3535A, Philips	10	N	
	Neonatal (infant) Incubator			
15	Vita Thermocare, Weyer	09	N	
	Infant Warmer			
16	Babytherm 8010, Dräger	01	N	
41	BabyWarmer 50W, KanMed	06	N	
	Fluid Warmer			
3	Buddy, Belmont	10	N	
	Hypohyperthermia			
11	Medi-Therm II MTA 4702, Gaymar Industries,Inc.	04	N	
	Cell Saver			
10	Electa, Sorin Group Tested while restricted functioning	05	N	
	Surgical Navigation			
23	Vector Vision compact, BrainLAB	06	N	
67	DigiPointeur 6200 (Facial + Skull Surgery), Collin	09	N	

No. in test	Medical apparatus tested	Year of purchase	Interference Y/N Classific. N/L/S/U 100mW: …cm 500mW: …cm	Channel No. 1/ 11/ 36/ 64
	Heart Lung Machine			
13	S5, Stöckert; Tested with Heater Cooler (No.14)	09	**Y [9] Classific.: U** **100mW: 2cm** **500mW: 10cm**	 **11** **11**
	Heater/Cooler			
14	Heater Cooler 3T,Stöckert;Tested with S5(No.13)	09	N	
	Insufflator			
24	Pneumo Sure XL High Flow Insufflator, Strijker	09	N	
25	Abdominal CO2 Insufflator 16 ltr, Olympus	95	N	
27	CO2 Insufflator UHI-3, Olympus	06	**Y [10] Classific.: U** **500mW: 25cm**	 11
	Electrosurgery			
26	ForceTriad Z25393, Valleylab	07	N	
	RF Lesion Generator (Pain Management)			
9	System Model RFG – 3c Plus, Radionics	98	N	
	RF Generator for Endovenous Ablation			
63	RF Generator RFG 2, VNUS, Inc.	08	N	
	Laser			
22	Sharplan 1055, Laser Industries	91	N	
34	Eye laser Novus Omni, Coherent	05	N	
35	Eye laser Tango, Ellex	08	N	
39	Dermatology Laser V-beam, Candela	03	N	
	Bone densitometer			
56	Lunar Prodigy, General Electric	02	N	
	Mammography			
28	Lorad Selenica, Hologic Company	06	N	
29	Breast Biopsy Stereotactic Multicare Platinum, Hologic Company	06	N	

[9]) **Ch11** 100mW: 2cm from Flowprobe TX50 of Centrifugal Blood Pump System (make Biomedicus - Medtronic): The registration by the Flowprobe is incorrect (display flashes).
Ch11 at 500mW: 10cm from Flowprobe TX50: same behaviour.

[10]) **Ch11** 500mW: 25cm form frontside: Influence on “pressure” and “Flow”.
Ch11 500mW: 1cm from front side: fast beep: Alarm 5/sec. After switching off and on the apparatus returns to normal functioning. Other Channels and other powers; No interference.

No. in test	Medical apparatus tested	Year of purchase	Interference Y/N Classific. N/L/S/U 100mW: …cm 500mW: …cm	Channel No. 1/ 11/ 36/ 64
	Bucky room			
32 a-e	Bucky system Digital Diagnost, Philips; Includes: Bucky, Tube, Detector, Table, Controldesk, Phosphor system	08	N	
33 a-f	Triathlon Bucky Room (SEH), Oldelft (Canon) Includes: Bucky, Tube, 2 Detectors, Table, Controldesk, PC, Phosphor system	06	N	
	X-Ray Chest system			
48	Allura Xper FD-10, Philips Incl.: Table AD 5 Tilt Angio Diagnost, Operating Console, Electronic control cabinett	06	N	
	Stereotaxis system			
49	Navigant Stereotaxis, Inc. NZA25, Niobe Incl.: Monitor, Operating console, Electronic control cabinet	06	N	
	Cardiac Stimulator			
51	Micropace PTY Ltd EPS 320, Cardiac Stimulator, Bona Computech Light Incl.: Amplifier at HCK, Monitor + PC on Desk, Monitor EKG (No. 50)	09	N	
	Angiographic contrast Injector			
52	Mark V ProVis, Medrad	06	N	
	Pacemaker Programmer			
53	Type Vitatron, Medtronic 2090 (loan) **RF-connection not activated / not available**	90 (?)	N	
54	Merlin Patient Care System, Model 3650, St. Jude Medical **RF-connection not activated / not available**	09	N	
55	Zoom Latitude Programming System, Guidant 3120 (loan) Incl.: RF connection at 350 a 500 MHz	08 (?)	**Y [11] Classific.: U 100mW: 150cm 500mW: 150cm**	**1,11 11**

[11]) **Ch 1**: 100mW: At 150cm A Rate and V Rate not detected via RF connection. Programming head not disturbed at 0cm.
Ch 11: 100mW: At 150cm A Rate and V Rate not detected via RF connection. Programming head not disturbed at 0cm.
Ch 11: 500mW: At 150cm A Rate and V Rate not detected via RF connection. Programming head not disturbed at 0cm.
Ch 36: 500mW: No interference on RF connection and programming head.
Ch 64: 100mW: No interference on RF connection and programming head.

No. in test	Medical apparatus tested	Year of purchase	Interference Y/N Classific. N/L/S/U 100mW: …cm 500mW: …cm	Channel No. 1/ 11/ 36/ 64
	Breath Analysis			
64	MicroLyzer DP Plus, Quintron	06	**Y [12] Classific.: U** **100mW: 1cm** **500mW: 20cm**	 **11** **11**
	UV-B cabin			
40	UV 7001 (UV-B), Waldmann Medizintechnik	05	N	
	IR – Spectral Photometer (Laboratory Pharmacy)			
44	Avatar 370 DIGS, Nicolet	04	**Y [13)] Classific.: U** **500mW: 0cm**	 **36**
	Medicine Analyser (Laboratory Pharmacy)			
45	Medicine Analyser, Dade Behring.	09	N	
	Microplate Reader (Laboratory Pharmacy)			
46	Microplate Reader EL 808, BioTek	07	N	
	Mass Spectrometer (Laboratory Pharmacy)			
47	Discovery Max Finnigan Quantum, Thermo Together with Autosampler Plus	06	N	
	Automated Hematology Analyzer			
57	Sysmex Incl.: Cell Counter, Slide Preparation Unit, Automated Sedimentation Measurement	03	N	
	Blood Glucose Meter			
58	Accu-Check Inform II, Cobas, Roche	10 (?)	N	

[12]) **Ch 11**: 100mW: 1cm from the meters on the front side: Interference: 104mV is changed into 107mV.
Ch 11: 500mW: 20cm from the meters on the front side: Interference. At 0cm 104mV is changed into 1**1**7mV. **Note** that the required accuracy is ± 2mV (information from Internet).
Other Channels: No Interference.

[13]) **Ch 1** 100mW: 5cm from left side: Interference on successive spectra. Match over 10 spectra = 36% which is not acceptable for photometry. However: this is acceptable as interference protection.
Ch11 100mW: 0cm from left side: Interference on successive spectra. Match over 10 spectra = 30% which is not acceptable for photometry. However: this is acceptable as interference protection.
Ch 36 500mW: 0cm from left side: Interference on successive spectra. Match over 10 spectra results in wrong material (NaCl). This effect starts at 150cm (500mW is not a requirement: see report introduction).
Ch 64 100mW: 0cm from left side: Interference on successive spectra. Match over 10 spectra = 94% which is acceptable for photometry.

No. in test	Medical apparatus tested	Year of purchase	Interference Y/N Classific. N/L/S/U 100mW: …cm 500mW: …cm	Channel No. 1/ 11/ 36/ 64
	Blood Gas Meter / Analyser			
59	ABL800 Flex, Radiometer (Dep. HKCL) Incl.: PC-terminal and IT-Network Port	09	N	
62	Rapidlab 845, Bayer	03	N	
	Clinical Chemistry System (Dep. HKCL)			
60	Modular Analytics, Roche Incl.: ISE 900, P 800, E 170	06	N	
	Microbalance			
70	Microbalance AG 204 Delta Range, Mettler Toledo	03	**Y [14] Classific.: U 100mW: No Interf. 500mW: 0cm**	**--- 11**
71	Microbalance XP 204, Mettler Toledo	05	N	
	Aseptic Preparation Laboratory ABA (Pharmacy)			
72	Handheld Contamination Monitor UMo LB123, Berthold	97	N	
73	Radiation Monitor RTD Series 900 mini-monitor, Mini-Instruments, Ltd.	91	N	
74	Radiation Dose Kalibrator VIK 202, Veenstra Incl.: Ionisation chamber, PC, Screen,	05	N	
76	Quality Control System VCS-103 connected with Scanner VCS-101 (No. 77), Veenstra	06	N	
75	Well Meter (Put Kristal) VDA-101 Connected to VCS-103 (No.76), Veenstra	06	N	
77	Chromatogram Scanner VCS-101 Connected to VCS-103 (No.76), Veenstra	06	N	
78	Hand/Foot Radiation Contamination Detector VLB-202, Veenstra	06 (?)	N	
	Endoscope drying cabinet			
6	GV 700, Van Vliet	05	N	
	Endoscope washer / disinfector			
7	WD 440, Wassenburg	03	N	
	RF wireless sensorsystem (Lab Microbiology)			
65	WiSensys (868MHz?)	09 (?)	N	

[14]) **Ch 11** 500mW: 0cm from display: 1microgramm deviation.
Ch 11 200mW: 0cm from display: 0,1microgramm deviation.
Ch 11 100mW: 0cm from display: No deviation; No Interference.
Other Channels: No Interference

No. in test	Medical apparatus tested	Year of purchase	Interference Y/N Classific. N/L/S/U 100mW: …cm 500mW: …cm	Channel No. 1/ 11/ 36/ 64
	Oxygen Detection			
61	Airmaster II, Linde Gas	08	N	

5.4 Summary of results

A summary of all influenced medical apparatuses is given in Table 5.3 below.
Table 5.3 is a summary from table 5.2

Table 5.3: Summary of all tested medical apparatuses that were influenced and the separation distance d per apparatus (at 100mW and 500mW).

No. in test	Medical apparatuses tested	Year of purchase	Separation distance d [cm] and Classification: L / S / U	
			At 100mW	At 500mW
	Volumetric Infusion Pump			
20	Model 598, Ivac	03	**20cm U**	**30cm U**
	Monitor/Meter			
69	Cardiac Output Meter Vigilant Vig 2E, Edwards	09	**N 15)**	
	Heart Lung Machine			
13	S5, Stöckert; Tested with Heater Cooler (No.14)	09	**2cm U**	**10cm U**
	Insufflator			
27	CO2 Insufflator UHI-3, Olympus	06	**N**	**25cm U**
	Pacemaker Programmer			
55	Zoom Latitude Programming System, Guidant 3120 (loan) Incl.: RF connection at 350 a 500 MHz	08 (?)	**150cm U**	**150cm U**
	Breath Analysis			
64	MicroLyzer DP Plus, Quintron	06	**1cm U**	**20cm U**
	IR – Spectral Photometer (Laboratory Pharmacy)			
44	Avatar 370 DIGS, Nicolet	04	**N**(acceptable interference)	**0cm U**
	Microbalance			
70	Microbalance AG 204 Delta Range, Mettler Toledo	03	**N**	**0cm U**

[15]) Restricted test due to failing test features: Only temperature indication was active; no curves on screen; no cardiac output measurement was running.

Full details about the interference reactions and the WLAN Channels are given in Table 5.2.

5.5 Graphical presentation of results

The test results are presented in the tables and graphs on the following page. Table 5.4 is directly copied from the summary of results in Table 5.3 in **Paragraph 5.4.** In the graphs of Figures 5.1 and 5.2 the following is depicted:

- The percentage of medical apparatuses that was disturbed at a distance **d** or higher. This percentage (%) is along the vertical axis; the distance **d** (in cm) is along the horizontal axis. The curves with the black dot markings belong to the results in Table 5.4 for 100mW and 500mW respectively.

From Figure 5.1 for example it can be concluded that at distances above 15cm about 3% of the medical apparatuses tested was disturbed by the WLAN signal 100mW. The continuous graphs are the theoretical field strength at distance **d** from WLAN antennas according to the basic formula $E = 7 \times (\sqrt{W}) / d$ in which W is power in watt (See **Literature [5]).** This field strength must be taken from the right vertical axis in the graphs of Figure 5.1 and Figure 5.2. Two examples:

- Example 1 (Figure 5.1): At 50cm from a WLAN 100mW antenna (dipole) the field strength is about 4,4 V/m.
- Example 2 (Figure 5.2): At 50cm from a WLAN 500mW antenna (dipole) the field strength is about 9,9 V/m.

In the Table 5.4 below the disturbances found are listed in order according to the separation distance **d** at which influence occurred by **100mW** and **500mW** WLAN signals respectively. Note that the two lists contain the same information, however in different order.

Table 5.4: The found disturbances listed in order of separation distance at 100mW and 500mW respectively (The two lists contain the same information, however in different order).

At 100mW

No. in Test	Separation distance d [cm] At 100mW	At 500mW
55	150cm **U**	150cm **U**
20	20cm **U**	30cm **U**
13	2cm **U**	10cm **U**
64	1cm **U**	20cm **U**
27	-	25cm **U**
44	-	0cm **U**
70	-	0cm **U**
69	-	-

At 500mW

No. in Test	Separation distance d [cm] At 100mW	At 500mW
55	150cm **U**	150cm **U**
20	20cm **U**	30cm **U**
27	-	25cm **U**
64	1cm **U**	20cm **U**
13	2cm **U**	10cm **U**
44	-	0cm **U**
70	-	0cm **U**
69	-	-

Conclusions from the graphs in Figure 5.1 and Figure 5.2:

- For **100mW** the distance at which 3% of the tested medical apparatuses was influenced is about 15cm;
- For **500mW** the distance at which 3% of the tested medical apparatuses was influenced is about 25cm;

- As mentioned above already, the 3% point for 100mW is at about 15cm. As can be seen from Figure 5.2 the 3% point for 500mW is at about 25cm. This shift in distance (about a factor 2) is comparable to the figure that the formula E = 7 x (√W) / d would imply (from 100mW to 500mW implies a shift of √5 = 2,24);
- The characterisations of the disturbances (in this study all U) are indicated in both diagrams.

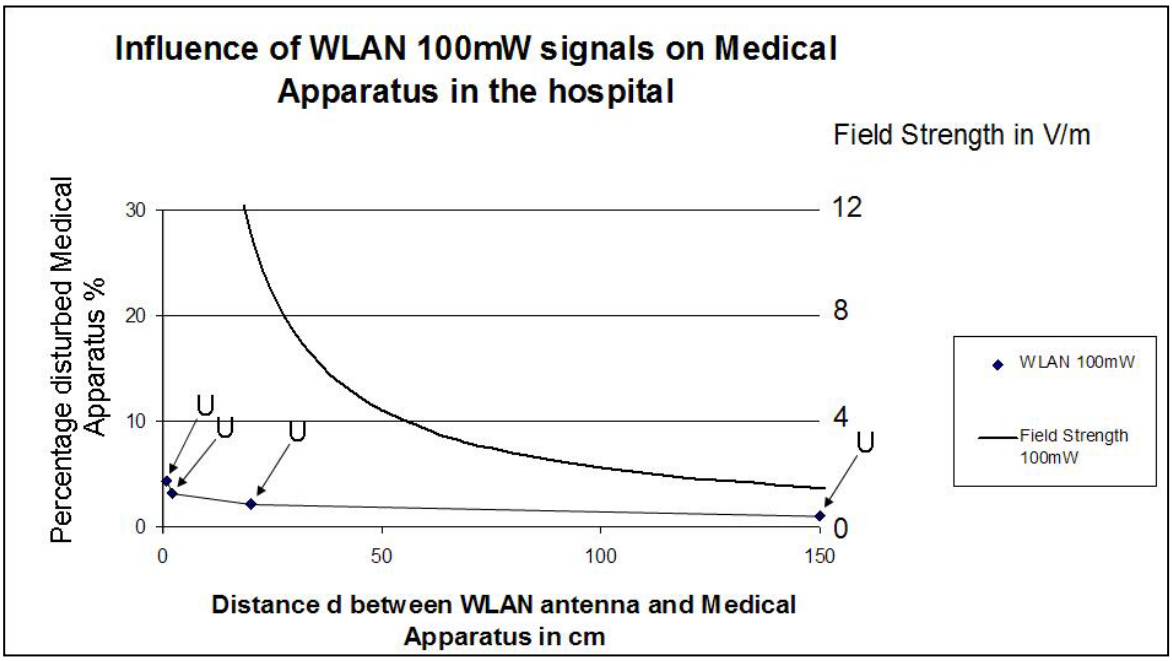


Figure 5.1: Influence of WLAN 100mW signals on medical apparatuses in the hospital.

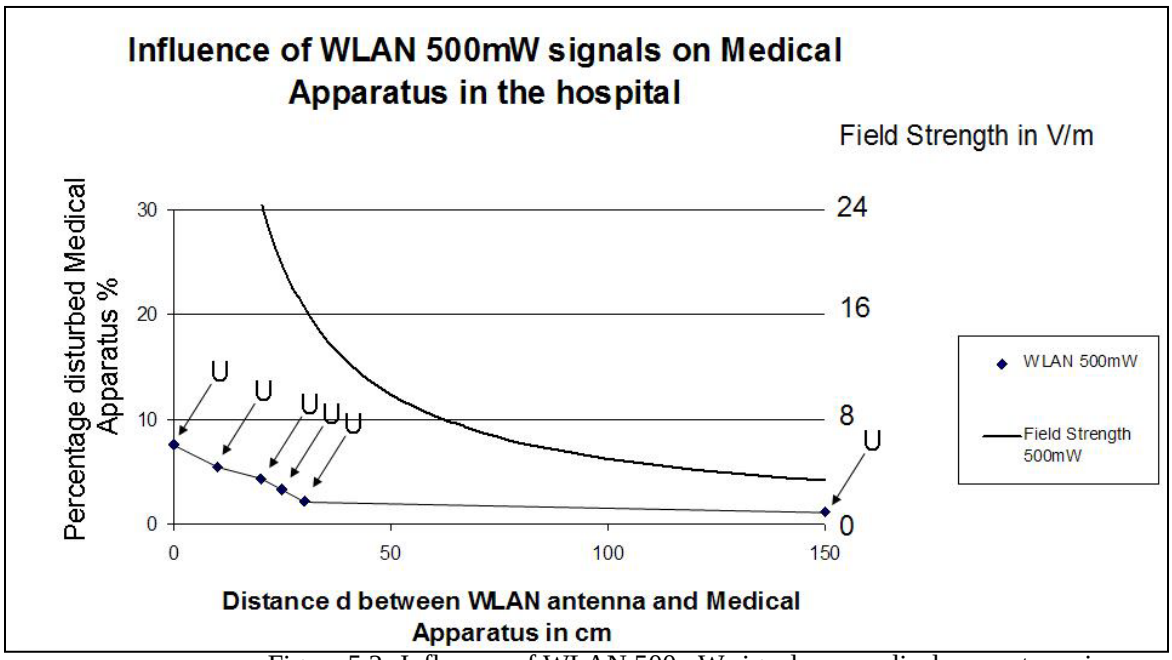


Figure 5.2: Influence of WLAN 500mW signals on medical apparatuses in the hospital.

5.6 Comparison of WLAN results to GSM results

Interpretation of WLAN results as presented in the **Paragraph 5.5** is possible by comparing them with results from comparable research on GSM mobile phones. In Figure 5.3 the results from research on GSM mobile phones are depicted (copied from **Literature [5]** and **[6]**).

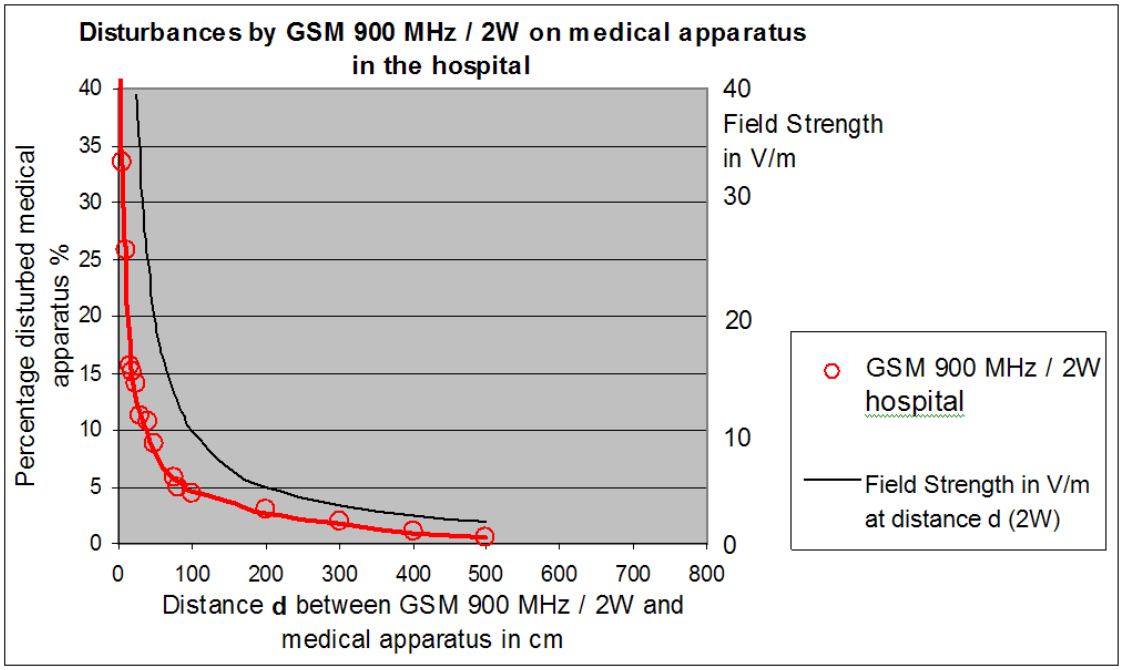


Figure 5.3: Disturbances by GSM 900 MHz / 2W on medical apparatus in the hospital (copied from **Literature [5]** and **[6]**).

From the graph in Figure 5.3 it can be seen that at 150cm distance from GSM phones about 3% of the medical apparatus is disturbed. The distance at which 3% apparatus are disturbed is internationally advised as the separation distance to be kept [16]. As concluded in **Paragraph 5.5** the 3% point for WLAN 100mW lies at about 20cm. From this comparison it concludes that the ratio between the separation distances for GSM and WLAN is about a factor of 10.

[16]) It is generally advised not to have GSM phones transmitting within this distance from a medical apparatus (in hospital and in home environment). See for example:
- Hanada et al in IEEE Trans on EMC November 2000 **Literature [9]**,
- Health Devices November 2001 (ECRI) **Literature [10]**.
- Morrissey et al, Health Physics (2002) 82: pp 4 - 51 **Literature [11]**.
- A Netherlands regulation is: V-ICTN Recommendations **Literature [7]** based on **Literature [5]** and referring to **Literature [3]**.

6 Signature

Author
R. Hensbroek, M.Sc.
Project manager

Signature

Approved by
R.A. Bezemer M.Sc. MTD
Peer review

Signature

A Functional modes of all tested medical apparatuses

In Table A.1 below details can be found about the functions that the medical apparatuses performed during interference testing (including power situation as far as relevant). Apparatuses are tabulated in the same order as in the other tables in this report.

Table A.1: Functional modes of all tested medical apparatuses and specification of the power source (mains or battery).

No. in test	Medical apparatus tested	Year of purchase	Functional modes of medical apparatuses
	Ventilator		
4	Savina (Transport Ventilador), Dräger	10	SIMV Autoflow, VT=500ml, f=16, PEEP = 5mbar.
36	Bipap Knight Star 335, Nellcor Puritan Bennett	00	Functioning; Normal use settings.
37	Bipap Harmony, Respironics, Inc.	10	Functioning; Normal use settings.
42	Babaylog 2000, Dräger In transport Incubator 5400 together with No. 43	04	Functioning; Normal use settings.
66	Leoni 2 Neonatal ventilator, Heinen und Löwenstein (Accutronic)	10	Tested with testlung. Mode: SIPPV = Synchronous Inspirative Positive Pressure Volume.
	Syringe Pump		
2	Argus 600 Green Stream SY-P, Argus Medical	05	Mounted in docking station; 60 ml/h.
12	Orchestra NL Module DPS, Fresenius Vial Tested in Orchestra Base Primea	04	Functioning in Orchestra Base Primea.
	Volumetric Infusion Pump		
20	Model 598, Ivac	03	Normal use infusion rate.
	Monitor/Meter		
18	Patient Monitor Intellivue MP5, Philips	09	Powered from mains and from internal battery. Tested with ECG simulator.
1	Patient Monitor MP70 (Intellivue M8007A),Philips	09	ECG, ABP (120/80), NiBP, HF (80), CO2, Temp, SpO2 (98), SaO2/Pleth, CVD (0). EKG-Simulator Lionheart 3, Biotek. SpO2 simulator Index 2, Biotek .
38	FMS Flexible Module Server, Philips; Tested with MP70 (No, 1)	04	

No. in test	Medical apparatus tested	Year of purchase	Functional modes of medical apparatuses
17	ST Analysis: STAN S31 Fetal Heart Monitor, Neoventa Medical AB	07	US Transducer, Cardiotocography-transducer (CTG), IUP. Tested with ECG simulator.
21	ST Analysis: STAN S21 Fetal Heart Monitor, Neoventa Medical AB	04	2 x US Transducer, Cardiotocography-transducer (CTG).
19	Fetal Monitor Viridia Series 50XM, M1350B, Hewlett Packard	99	2 x US Transducer, Cardiotocography-transducer (CTG). Tested with SpO2 simulator.
43	Oxygen Monitor MaxO2, Ceramatec In transport Incubator 5400 together with No. 42	97	Functioning.
69	Cardiac Output Meter Vigilant Vig 2E, Edwards. **Restricted test (no measurements on screen)**	09	Restricted test due to failing test features: Only temperature indication was active; no curves on screen; no cardiac output measurement was running.
	Ultrasound Diagnostic Scanner		
30	Xario XG, Toshiba; Tested with probe 12L5	09	Functioning at normal use settings; Tested with probe 12L5.
	Dialysis		
8	5008 Fresenius Medical care	07	Bloodflow 30 ml/min.
8b	Aqua Uno RO = Reverse Osmosis, Fresenius Medical care; Tested with 5008 (No 8)	08	Display: 8 microseconds.
	EKG		
50	Electrofysiologic System Labsystem Pro, C.R. Bard, Inc. Incl.: 2 Monitors in HCK, 2 Monitors + PC on Desk, EKG-amplifier, IC Module	00	Functioning at normal use settings; Tested with simulator Fluke MPS 450.
	External Defibrillator / Monitor		
5	Heartstart MRx M3535A, Philips	10	Performing defibrillations, EKG-Simulator Lionheart 3, Biotek. SpO2 simulator Index 2, Biotek.
	Neonatal (infant) Incubator		
15	Vita Thermocare, Weyer	09	Functioning, Normal use settings.
	Infant Warmer		
16	Babytherm 8010, Dräger	01	Functioning, Normal use settings.
41	BabyWarmer 50W, KanMed	06	Functioning; Normal use settings.

No. in test	Medical apparatus tested	Year of purchase	Functional modes of medical apparatuses
	Fluid Warmer		
3	Buddy, Belmont	10	Functioning.
	Hypohyperthermia		
11	Medi-Therm II MTA 4702, Gaymar Industries,Inc.	04	Warming up and Cooling down.
	Cell Saver		
10	Electa, Sorin Group **Tested while restricted functioning**	05	Tested during short start-up runs, Patient set Dideco CE 0123.
	Surgical Navigation		
23	Vector Vision compact, BrainLAB	06	Detecting three marker balls.
67	DigiPointeur 6200 (Facial + Skull Surgery), Collin	09	Tested during marking at the skull with the “pen”.
	Heart Lung Machine		
13	S5, Stöckert; Tested with Heater Cooler (No.14)	09	Functioning at normal use settings.
	Heater/Cooler		
14	Heater Cooler 3T,Stöckert;Tested with S5(No.13)	09	Functioning: 38.0 0C.
	Insufflator		
24	Pneumo Sure XL High Flow Insufflator, Strijker	09	Functional: Normal use settings: 0,3 l/min CO2.
25	Abdominal CO2 Insufflator 16 ltr, Olympus	95	Functional: Normal use settings.
27	CO2 Insufflator UHI-3, Olympus	06	Functional: Normal use settings.
	Electrosurgery		
26	ForceTriad Z25393, Valleylab	07	Modes: Cut & Coagulating; “Ligasure” electrodes not connected.
	RF Lesion Generator (Pain Management)		
9	System Model RFG – 3c Plus, Radionics	98	Catheter immersed into saline solution. Tested in three modi: measurement/test, burning/treatment, Tip temperature controlled.

No. in test	Medical apparatus tested	Year of purchase	Functional modes of medical apparatuses
	RF Generator for Endovenous Ablation		
63	RF Generator RFG 2, VNUS, Inc.	08	Tested with electrode in saline solution: RF endovenous ablation: 15W phase 1 and 25W phase 2.
	Laser		
22	Sharplan 1055, Laser Industries	91	Tested in functional standby (laser at a low level). All electronics functioning.
34	Eye laser Novus Omni, Coherent	05	Functioning; Normal use settings.
35	Eye laser Tango, Ellex	08	Functioning; Normal use settings.
39	Dermatology Laser V-beam, Candela	03	Tested during calibration: 4 J/cm2 during 40msec.
	Bone densitometer		
56	Lunar Prodigy, General Electric	02	Tested during built-in quality control.
	Mammography		
28	Lorad Selenica, Hologic Company	06	Image taken from a phantom; Vertical movement included in test.
29	Breast Biopsy Stereotactic Multicare Platinum, Hologic Company	06	Functioning at normal use settings
	Bucky room		
32 a-e	Bucky system Digital Diagnost, Philips; Includes: Bucky, Tube, Detector, Table, Controldesk, Phosphor system	08	Normal use settings. Images taken.
33 a-f	Triathlon Bucky Room (SEH), Oldelft (Canon) Includes: Bucky, Tube, 2 Detectors, Table, Controldesk, PC, Phosphor system	06	Normal use settings. Images taken.
	X-Ray Chest system		
48	Allura Xper FD-10, Philips Incl.: Table AD 5 Tilt Angio Diagnost, Operating Console, Electronic control cabinett	06	Normal use settings. Images taken.
	Stereotaxis system		
49	Navigant Stereotaxis, Inc. NZA25, Niobe Incl.: Monitor, Operating console, Electronic control cabinet	06	Functioning at normal use settings.

No. in test	Medical apparatus tested	Year of purchase	Functional modes of medical apparatuses
	Cardiac Stimulator		
51	Micropace PTY Ltd EPS 320, Cardiac Stimulator, Bona Computech Light Incl.: Amplifier at HCK, Monitor + PC on Desk, Monitor EKG (No. 50)	09	Functioning at normal use settings.
	Angiographic contrast Injector		
52	Mark V ProVis, Medrad	06	Functioning at normal use settings; Tested while injecting.
	Pacemaker Programmer		
53	Type Vitatron, Medtronic 2090 (loan) RF-connection not activated / not available	90 (?)	Tested with pacemaker EnTrust (DDE-DDDR); Read-out(EKG) and programmed via programming head.
54	Merlin Patient Care System, Model 3650, St. Jude Medical **RF-connection not activated / not available**	09	Tested with ICD Promote RF (S/N 397678); Read-out(EKG) and programmed via programming head.
55	Zoom Latitude Programming System, Guidant 3120 (loan) Incl.: RF connection at 350 a 500 MHz	08 (?)	Tested with ICD Guidant Renewal 4 RF (DDDR – Mode H 230 S/N 202342); Read-out(EKG) and programmed.
	Breath Analysis		
64	MicroLyzer DP Plus, Quintron	06	Functioning; Normal use settings.
	UV-B cabin		
40	UV 7001 (UV-B), Waldmann Medizintechnik	05	Functioning; Normal use settings; Tested during Countdown.
	IR – Spectral Photometer (Laboratory Pharmacy)		
44	Avatar 370 DIGS, Nicolet	04	Analysing a polystyrene sample.
	Medicine Analyser (Laboratory Pharmacy)		
45	Medicine Analyser, Dade Behring.	09	Analysing E2 Theophylline (control liquid). 20 min.
	Microplate Reader (Laboratory Pharmacy)		
46	Microplate Reader EL 808, BioTek	07	Microplate filled up with white and yellow test liquid.

No. in test	Medical apparatus tested	Year of purchase	Functional modes of medical apparatuses
	Mass Spectrometer (Laboratory Pharmacy)		
47	Discovery Max Finnigan Quantum, Thermo Together with Autosampler Plus	06	Masses: 182, 508, 997.
	Automated Hematology Analyzer		
57	Sysmex Incl.: Cell Counter, Slide Preparation Unit, Automated Sedimentation Measurement	03	Tested during full processing of 3 test samples.
	Blood Glucose Meter		
58	Accu-Check Inform II, Cobas, Roche	10 (?)	Tested during full processing of test-strip and testliquid. No mains power.
	Blood Gas Meter / Analyser		
59	ABL800 Flex, Radiometer (Dep. HKCL) Incl.: PC-terminal and IT-Network Port	09	Tested during full measurement process including database (network).
62	Rapidlab 845, Bayer	03	Tested during full processing of quality control sample.
	Clinical Chemistry System (Dep. HKCL)		
60	Modular Analytics, Roche Incl.: ISE 900, P 800, E 170	06	Tested during full measurement process.
	Microbalance		
70	Microbalance AG 204 Delta Range, Mettler Toledo	03	Weighing 8,7113g.
71	Microbalance XP 204, Mettler Toledo	05	Weighing.
	Aseptic Preparation Laboratory ABA (Pharmacy)		
72	Handheld Contamination Monitor UMo LB123, Berthold	97	Functional (switched on).
73	Radiation Monitor RTD Series 900 mini-monitor, Mini-Instruments, Ltd.	91	Functional (switched on).
74	Radiation Dose Kalibrator VIK 202, Veenstra Incl.: Ionisation chamber, PC, Screen,	05	Measuring: 105,5 MBq.
76	Quality Control System VCS-103 connected with Scanner VCS-101 (No. 77), Veenstra	06	Measuring: Cobalt 57: 122 keV.
75	Well Meter (Put Kristal) VDA-101 Connected to VCS-103 (No.76), Veenstra	06	Measuring: Cobalt 57: 122 keV.

No. in test	Medical apparatus tested	Year of purchase	Functional modes of medical apparatuses
77	Chromatogram Scanner VCS-101 Connected to VCS-103 (No.76), Veenstra	06	Measuring: Cobalt 57: 122 keV
78	Hand/Foot Radiation Contamination Detector VLB-202, Veenstra	06 (?)	Contamination simulated with Cobalt 57: 6,1 Bq/cm2.
	Endoscopes drying cabinet		
6	GV 700, Van Vliet	05	Functioning.
	Endoscope washer / disinfector		
7	WD 440, Wassenburg	03	Functioning: washing / disinfecting.
	RF wireless sensorsystem (Lab Microbiology)		
65	WiSensys (868MHz?)	09 (?)	Three transmitters and a base station were tested while functioning normally.
	Oxygen Detection		
61	Airmaster II, Linde Gas	08	Tested while O2 concentration was reduced with N2.

B WLAN test set-up

1 Measurement Equipment to monitor testing
- Spectrum analyser: fsh manufactured by Rohde & Schwarz;
- Attenuator 20dB.

2 Hardware in the test set-up:
- 2 PC's / 8 AP's (in this way combining 802.11 a, b, g and n in one test);
- Amplifiers at 2,4GHz and at 5 GHz to start testing on every medical apparatus with 2 channels at higher power levels than normal;
- Medical Apparatuses were placed on a wooden cart.

Note: 4 Access Points simulated 4 clients. These 4 A.P.s were brought close to the medical equipment. 4 other A.P.s communicated with the "client-simulating-A.P.s". The A.P.s were Lancom A.P.s (Lancom L-54 dual wireless) with Atheros Chipsets (=Printed Circuit Boards). The A.P.s fulfilled the requirements of IEC/EN 60601-1-2 (for EMC on medical equipment). The results of the interference tests (**Paragraph 5**) are considered independent from the make of the A.P.s.

Note: Antennas were normalized antennas. No directional antennas were used. Within a distance of 15cm from the antennas far field conditions do not apply for 2,4GHz. Within a distance of 8cm from antennas far field conditions do not apply for 5GHz. Testing at distance 0cm means that the antenna is held against the medical apparatus. At this distance no far field conditions occur. In the near field it is not possible to apply the (simple) standard far field formulas that relate field strength to radiated power at a certain distance. In the far field however such calculations can be performed in principle for estimating the field strength.

The diagram in Figure B.1 below depicts the test set-up. See also the photographs in **Appendix C** to this report.

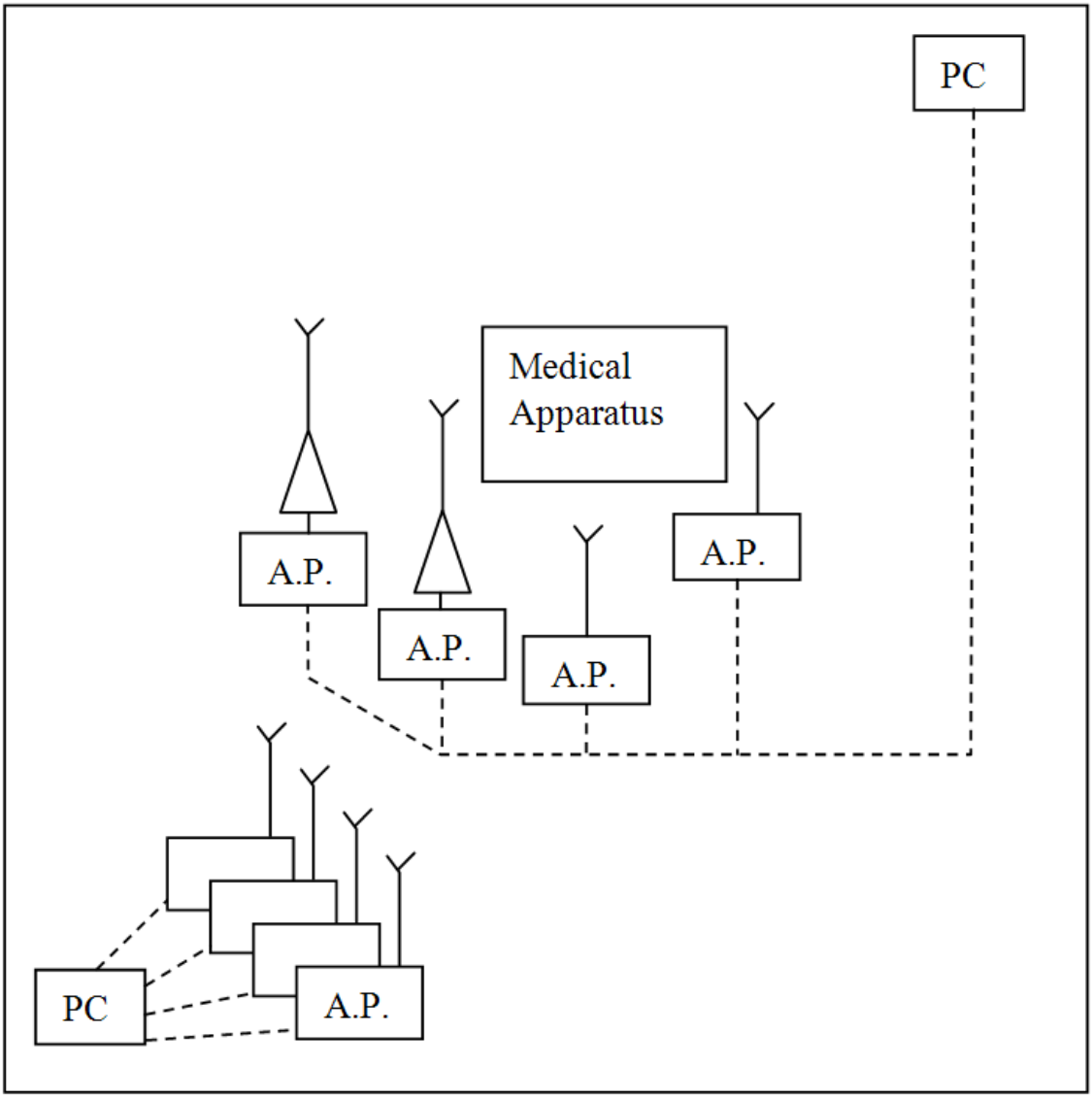


Figure B.1: Test set-up with 4 transmitting antennas and 4 receiving antennas. Each of these groups of antennas was connected to a separate PC.

C Photographs

Figure C.1 shows the test signal of Channel 1 with short packages. The photo is obtained with a spectrum analyzer at zero span. The time base was 0,1ms/division (upper trace), 1ms/div (middle trace) and 10ms/div (lower trace). As indicated in the montage by accolades, the upper trace can be recognized as being a part of the middle trace, etcetera.

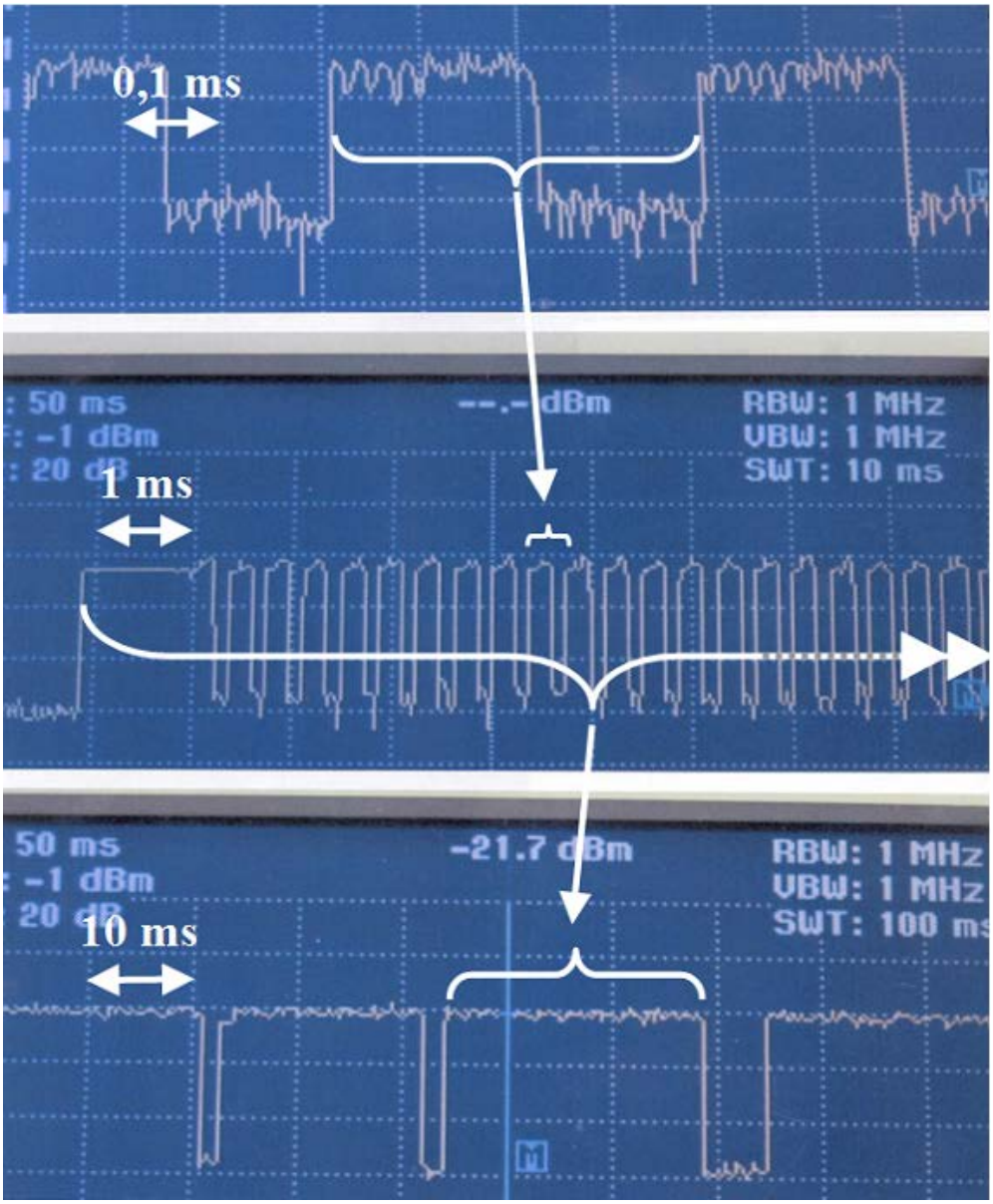


Figure C.1 Test signal of Ch1 with short packages. The time base: 0,1ms/division (upper trace), 1ms/div (middle trace) and 10ms/div (lower trace).

In the photographs following below a transmitting antenna in verification is shown (Figure C.2), two test set-ups for medical apparatuses (Figure C.3, C.4), the cart with receiving antennas (Figure C.6) and typical test situation examples with laboratory apparatus and medical apparatuses (Figures C.5, C.7 to C.10).

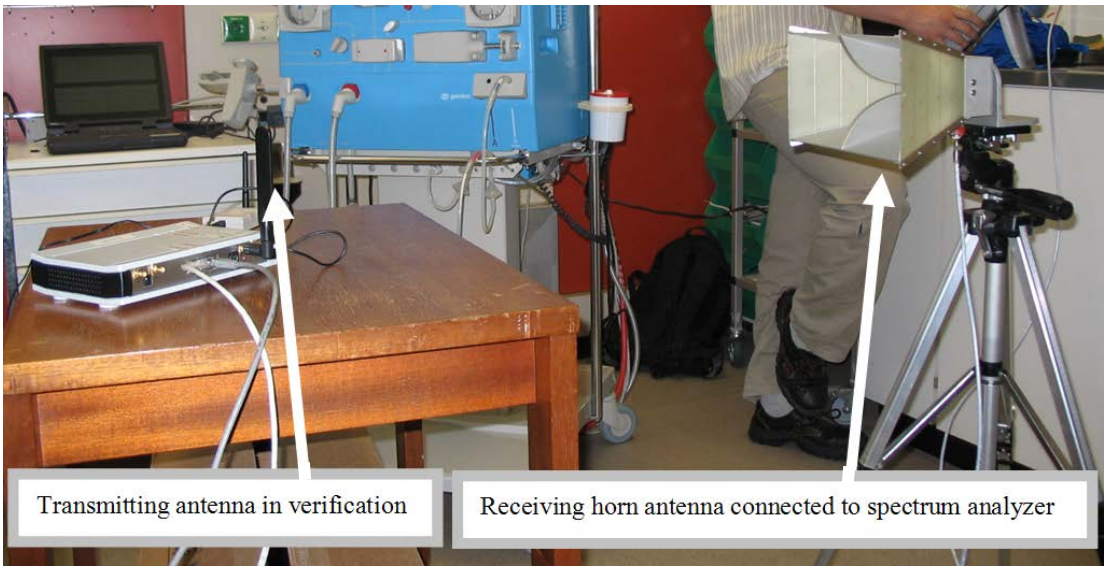


Figure C.2. Transmitting antenna in verification.

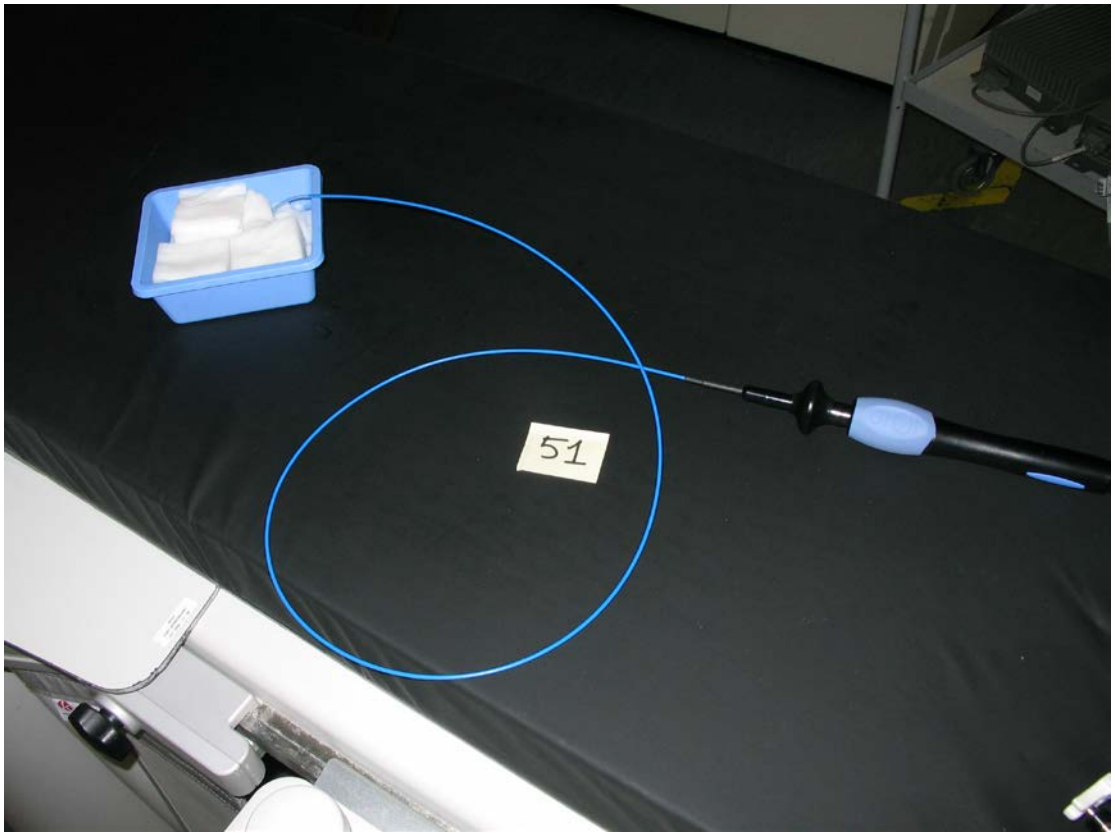
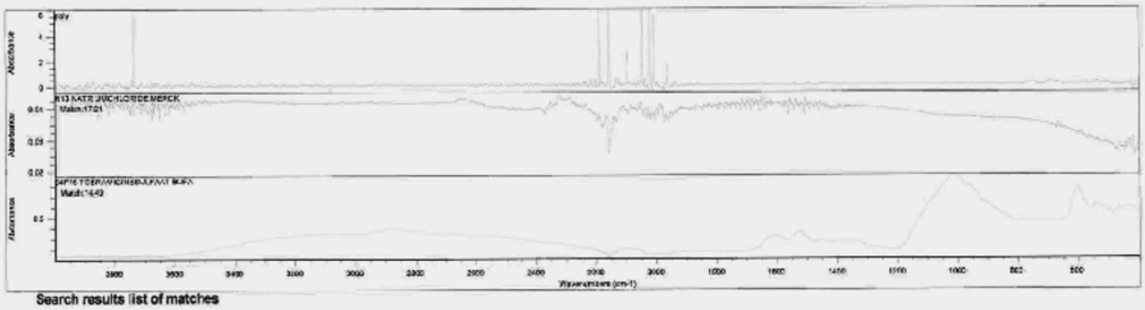


Figure C.3. Test set-up: Loop-electrode for Electrophysiological measurements inserted in saline (Apparatus No. 51).

Search results for: poly
Date: Fri Jun 18 14:40:58 2010 (GMT+02:00)
Search algorithm: Correlation
Regions searched: 3495.26-650.00



Search results list of matches

	Index	Match	Compound Name
1	71	17.21	N13 NATRIUMCHLORIDE MERCK
2	19	14.49	04F16 TOBRAMICINESULFAAT BUFA
3	8	11.47	03H34 AMINOHYDROXYPROPYLIDEENDIFOSFONAAT (APD) APOTHEEK HAAG
4	141	10.46	NITROUS OXIDE GAS (GAS CELL)
5	225	9.58	06D11 TOBRAMYCINESULFAAT
6	61	9.47	04F25 SORBISTERIT PDR FRESENIUS
7	91	8.49	OCTANE-D18,98+ ATOM % D
8	786	5.88	clioquinol placebo
9	235	5.81	Methylcellulose
10	286	5.67	antifoam emulsie 6%

Figure C.4. Interference: Spectrophotometer identifies Polystyrene incorrectly as Natriumchloride. The low Match (17.21) warns the user that the result is suspect. (Apparatus No. 44)

Figure C.5 Test set-up Laboratory apparatus.

Figure C.6.

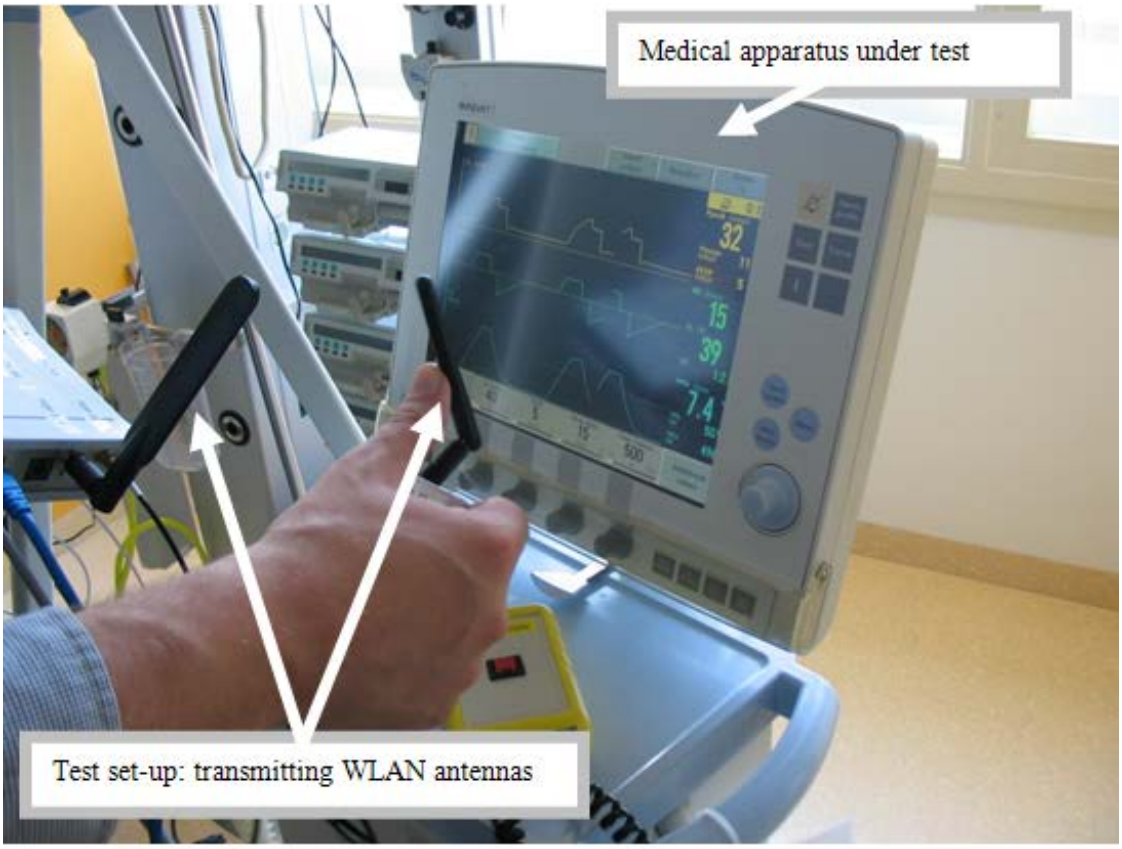


Figure C.7.

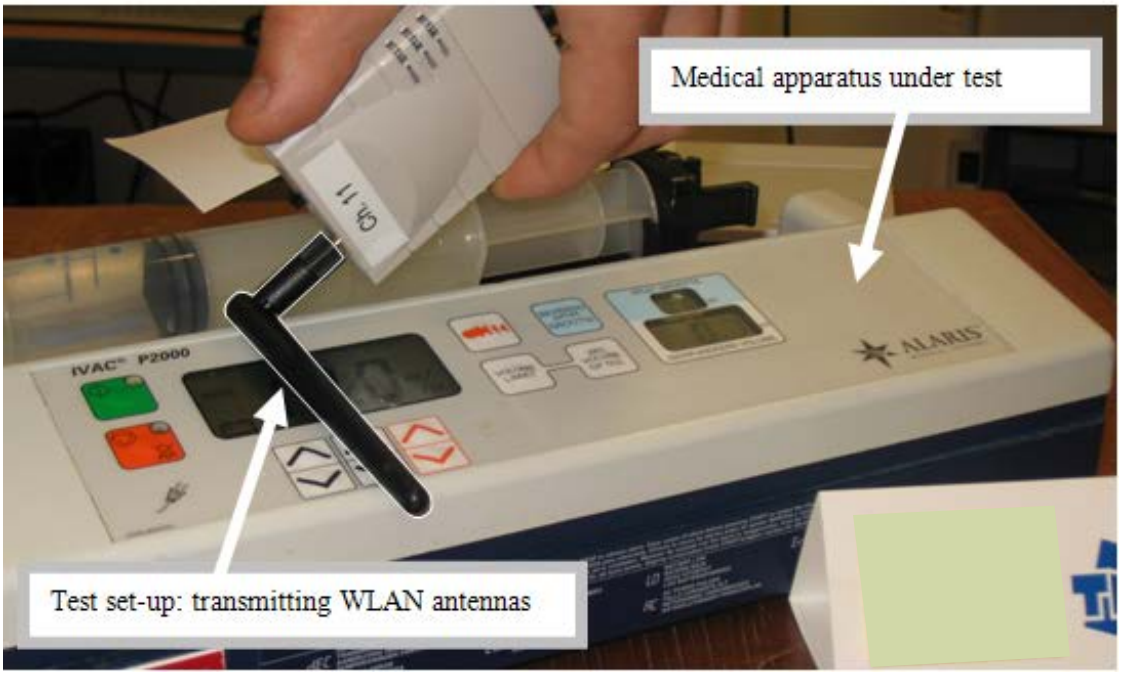


Figure C.8.

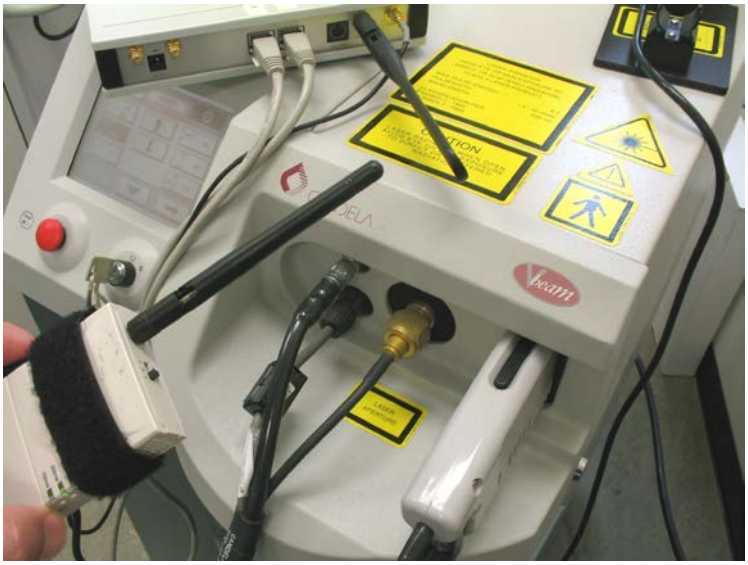


Figure C.9

Figure C.10

D Literature

1 TNO report “96 Medical Apparatuses tested for interference by WLAN/WiFi signals” R. Hensbroek, TNO Quality of Life, Report Number: KvL/P&Z 2007.117 dated September 2007. See: http://www.TNO.nl/WLAN-Zorg

2 Magazine “Technologie in de Gezondheidszorg” (NL language). April 2005, Number 4, 21st Issue, pp.5-6

3 Recommendations regarding the use of pocket telephones within health care institutions 1995, VIFKA, 1 September 1995 (VIFKA is now called “Vereniging ICT Nederland”).

4 IEC 60601-1-2: 2007 Medical electrical equipment – Part 1-2: General requirements for basic safety and essential performance - Collateral standard: Electromagnetic compatibility - Requirements and tests. Third edition.

5 TNO report “Effects on medical equipment at home of pocket phones and the like – field measurements”, TNO Prevention and Health, TNO Research report PG/TG/00.050 (28 April 2000)
For medical apparatus this report refers to:
Influence of 2W GSM pocket phones on 205 medical apparatuses: field measurements. TNO report TG/95.044. 1 August 1995 (NL Language).

6 R. Hensbroek, Interference by handheld telephones on medical equipment (NL language). In magazine: “Klinische Fysica”. December 2000.

7 Recommendations for the use of GSM and cordless telephones near electronic medical equipment for home care, 25 October 2000. This document has been drawn up by the Telecommunication branch of the Netherlands Association for Information and Communication Technology (V-ICTN). It is published on the internet site of the Netherlands Ministry of Welfare, Health and Sports.
Those recommendations refer to the still applicable recommendations in Literature **[3]:** Recommendations regarding the use of pocket telephones within health care institutions 1995, VIFKA, 1 September 1995 (VIFKA is now called “Vereniging ICT Nederland”).

8 IEC TR 60513 (1994) Fundamental Aspects of Safety Standards for Medical Electrical Equipment.

9 Hanada et al: Electromagnetic Interference on Medical Equipment by Low power Mobile Telecommunication Systems. IEEE Transactions on Electromagnetic Compatibility, Vol. 42, No. 4, November 2000, pp. 470 476.

10 ECRI Health Devices 30 (11), November 2001: Wireless Communication Devices and Electromagnetic Interference, pp. 403-409.

11 Morrissey et al: Characterization of Electromagnetic Interference of Medical Devices in the Hospital due to Cell Phones. Health Physics, January 2002, Volume 82, Number 1, pp 45-51.