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Effects on medical equipment at home of pocket phones and the like – field measurements

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Summary of 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.

Results summarized

Medical equipment at home is comparably sensitive to fields from pocket telephones as medical equipment in the hospital: within 1 to 2 m, interference can occur. Therefore a warning about the sensitivity of extramural equipment to interference remains to be justified. On the other hand, too much fear for influences of this type is needless. No indications were found for wheelchairs being disturbed by pocket phones carried by passers-by; however, for the sake of security, users of wheelchairs who want to use a hand-held telephone themselves should first switch off their wheelchair. Foreign publications indicate that apnoea monitors must be made less sensitive if this has not been done yet. Warnings against possible interference must be added to pocket telephones and be placed on the Internet (in most cases this already happens on the basis of publications from 1995). Warnings should be added to medical equipment as well.

The new draft second edition of the EMC standard for medical equipment (applicable from around 2001) prescribes manufacturers of medical equipment to specify at how close distances near medical equipment mobile communication devices may be used in relation to their transmitted power. It is therefore necessary that manufacturers of pocket phones and the like indicate this power and that they indicate it as <u>maximum</u> power. Annex C to this report gives examples of this.

Results in figures

A total of 100 medical apparatuses for extramural use were tested. Tests were performed with GSM 2 W, GSM 8 W, DCS 1800, DECT and CT 0. Of the 100 medical apparatuses tested, 42 appeared to be immune to all sources of interference applied. The greatest percentage of disturbance occurred with the GSM 8 W [1] source: 57 medical apparatuses appeared to be sensitive. The greatest distance at which interference could occur was 300 cm (respiratory support device). Of the 57 apparatuses sensitive to GSM 8 W, 19 (33%) reacted in a way that could impair safety. Of the 37 apparatuses sensitive to GSM 2 W, 17 (46%) reacted in an unsafe manner. For DCS 1800 the percentage of sensitive apparatuses was 10%, for DECT (1900 MHz) 4%, and for CT 0 (40 MHz) 3%. With all interference sources unsafe reactions occurred as well. These unsafe reactions occurred at all distances, not primarily at the shortest distances. Respiratory support devices belonged to the most sensitive apparatuses and also mostly elicited unsafe reactions. Several other apparatuses were only unsafe at distances of some centimetres until some decimetres (e.g. blood glucose monitors, infusion pump for medicine, social alarm equipment, wheelchairs and scooters). Of the 34 wheelchairs and scooters tested, 13 reacted, but the transmit-

[1] GSM 8 W is not being used in the Netherlands any more.

ting antenna of the pocket telephone had to be very close to the electronic circuits of the wheelchair concerned to elicit a reaction.

Other reactions can be described as unpleasant, but it has to be noted that several unpleasant reactions combined may be hazardous because they hide real danger.

Warnings

The new DCS 1800 system results in few interferences. The overall conclusion is that medical equipment for home use is slightly less sensitive to interference than medical equipment in the hospital. However, outside the hospital stronger sources of interference are to be expected, such as vehicles close to the window, and no professional personnel is available if interference problems occur. Therefore, a serious warning statement should be addressed to both manufacturers of pocket phones and producers of medical equipment. That warning statement is that, on the one hand, medical equipment for home use must be made less sensitive to disturbing fields emitted by pocket phones and, on the other, manufacturers of pocket phones should (continue to) include warnings with the phones and on the Internet against using these phones near medical equipment. Medical apparatuses must be accompanied by a warning against possible interference influences. A more or less reassuring conclusion from the investigation is that no high sensitivities were found for wheelchairs: some wheelchairs were sensitive but only if the antenna of the transmitting device was brought very close to the electronic circuits of these wheelchairs.
Unless manufacturers of wheelchairs fully guarantee the insensitivity of their products, wheelchair users should bring their wheelchair in a safe situation (switch it off) before they make phone calls themselves. The results of this study do not indicate that pocket phones that are at a distance of more than a few decimetres, for example in the hands of passers-by, do disturb wheelchairs.

Keywords
pocket phone, mobile phones, interference, GSM, medical equipment, ElectroMagnetic Compatibility (EMC), extramural

(End of summary)

Remark: An English summary has been distributed earlier under full responsibility of TNO. When translating the report in full the above version of the summary resulted, containing editorial changes.

Contents

1 Introduction

1.1 Research questions

The research question can be formulated as follows.

It is increasingly common practice that patients are discharged form the hospital with electromedical equipment for treatment at home. Medical equipment in the hospital is more or less sensitive to disturbances. These facts make it relevant to explore the possibility that electronic medical equipment used at home is influenced by electromagnetic fields. Possible sources of interference include wireless (radio)-communication devices.

At the request of Zorgonderzoek Nederland, TNO conducted the field measurements reported here into possible influences on electromedical equipment used by patients at home. In this context, 'at home' should be taken in a broad sense. The equipment referred to is electromedical equipment that can be used by or for patients outside the hospital. Such equipment may be a wheelchair for outdoor use or an insulin pump carried on the body. The home situation differs from the hospital in that supervision of the use of equipment is lacking at home. The user must be confident that the equipment will function properly under whatever conditions.

The study covered both currently available and foreseeable telecommunication tools, with a specific focus on the target group, the site of use and the extent of penetration.

The following concrete questions were asked.

To what extent is it justified today to have complex medical technological equipment used in the patients' home (for the chronically ill, for example)? To what extent can currently present sources of electromagnetic fields, such as GSM (car) phones and other communication systems operating via the air disturb medical equipment?

What role play mobile means of communication, and what role will such tools anticipated in the foreseeable future play, in the home environment, also in the light of the expected growth of the use of networks operating via the air and soon via satellites?

Do the increasingly complex electronic functions built into medical equipment, in combination with the explosive penetration of mobile communication tools, introduce a real risk of disturbances in medical equipment? To what extent is medical equipment shielded against such disturbances? The coincidence is very hard to trace for lay users, and this will be more problematic as the technology becomes more complex.

The aim of this study was to quantify, by means of laboratory and field measurements, disturbances of medical equipment in extramural care arising from the explosive penetration of pocket phones and similar mobile communication tools in society. The results should yield concrete suggestions for improvement and for new, reproducible testing methods that can be applied for future extramural electromedical equipment.

1.2 Importance of the research

Medical technological provisions are applied in the home situation on an increasingly larger scale because their use is associated with various advantages: they enable patients to be in their own home, a higher level of subjective well-being and, last but not least, lowered costs relative to intramural care. Increasingly complex electronics are built into these provisions, and it is exactly these electronics that help enable their extramural application. When these medical provisions are applied in the home situation, it is rarely explored exhaustively whether such an application is justified with a view on disturbing influences. In evaluating the general infrastructure in the patient's home, the influence of possible sources of interference should be taken into account because they might adversely affect the treatment and care of the chronically ill, for example.

In addition to the well-known disturbance by electronic equipment such as television, radio and the phones referred to above, there are currently other devices such as the fax, the microwave oven or the inductive hot plate. Such equipment as vacuum cleaners, irons and electric heaters are also potential sources of interference. In specific cases, an important factor may also be communication equipment that must generate electromagnetic fields to be able to function, such as broadcasting stations and relay stations of communication systems. Our society is insufficiently aware of the potential hazards, which is reflected in the licences granted to radio amateurs: they are allowed to generate strong fields provided under the condition that they assist their environment in case of disturbances. On a distance of some metres form the transmitting aerial, the field strength may be tens of volts while the standard for insensitivity of medical equipment is only 3 V/m. Moreover, the current standard is confined to frequencies lower than 1000 MHz while many communication devices operate at much higher frequencies[2].

New means of communication are following each other in rapid succession and also come within the reach of private users. The complexity of society and the increasingly lower costs of advanced electronic circuits promote the current boom in mobile means of communication operating via the air. Whether this is a desirable trend is beyond the scope of this study. After all, their introduction occurs on a large scale and involves not one provider but an array of mutually competitive suppliers, for all age categories

[2] The 1st edition of this standard is now in force (reference [9] in Appendix E). The 2nd edition has been issued as a draft (reference [10]).

youngsters included. The best-known forms today are ATF3- and GSM phones[3], both as a pocket phone and as a car-bound variant.

Society is insufficiently aware that pocket phones are also sources of electromagnetic fields that can disturb (medical) equipment. Typical of the Dutch situation is that a high population density combined with an anticipated high degree of penetration of pocket phones result in a high coverage, which might increase the likelihood of 'incidents'.

These facts lead to the reasonable fear that the application of medical technology at home will introduce potential hazards. That this fear is not hypothetical was demonstrated by a TNO field study in health care institutions[4] [5] [6]. That study, which has resulted in precautionary measures in hospitals[7] , revealed that ca. 49% of intramural medical equipment is sensitive to the fields of GSM pocket phones with a transmitting power of 2 W. The effect of the standard 8 W car phone was not covered by that study because their use within care institutions is not a real option. In contrast, the 8 W [8] mobile car phone is potential source of disturbances indeed in the extramural situation because many users of medical equipment are traffic participants and because other traffic participants can be in their close proximity, for example just on the other side of a window. In particular, the intramural study has revealed that patient monitors, sphygmomanometers, respirators, incubators, infusion pumps, syringe pumps and other equipment are sensitive. The sensitivity of pacemakers and hearing aids is sufficiently known[9] [10] [11] to keep them outside the current extramural study.

It should be noted that, besides the risk of life-threatening disturbances, attention must be extended to more commonly occurring harmless but highly annoying disturbances. After all, in the home situation, users have to rely on themselves: in contrast to the

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[3] ATF3 = Auto Telephone, the third channel, was closed in the Netherlands in 1999. It will also be closed in other countries (the UK will close the TACS channel around 2005). GSM stands for Global System for Mobile Communications.

[4] Influence of 2 W GSM pocket phones on 205 medical apparatuses: field measurements. TNO research report TG/95.044. 1 August 1995, Reference [1].

[5] Influence of DECT pocket phones on 131 medical apparatuses: field measurements. TNO research report TG/95.045. 1 August 1995, Reference [2].

[6] Influence of CT 2 pocket phones on 106 medical apparatuses: field measurements. TNO- research report TG/95.046. 1 August 1995, Reference [3].

[7] VIFKA: Recommendations regarding the use of pocket telephones within health care institutions, Reference [4]

[8] GSM 8 W is not used in the Netherlands any more.

[9] Irnich et al., Electromagnetic interference of pacemakers by mobile phones. PACE 19 (October 1996), pp. 1431–1446.

[10] Schlegel et al., Electromagnetic compatibility of the in-vitro interaction of wireless phones with cardiac pacemakers. Biomedical Instrumentation & Technology, November/December 1998, pp. 645–655.

[11] T.L. Fry et al., Impact of CDMA wireless phone power output and puncture rate on hearing aid interference levels. Biomedical Instrumentation & Technology, January/February 2000, pp. 29-38.

situation in institutions, there is no medical or technical staff directly available. Also from a quality point of view and for the user's peace of mind, 'harmless disturbances' are highly undesirable.

Because the cause of disturbances is often irreducible, those involved rarely recognize them as disturbances. It has been established, for example, that certain apnoea monitors do not alert users to the presence of fields generated by broadcasting stations. Split responsibilities hinder a united tackling of this problem by authorities involved: each governmental body is just responsible for part of the problem.

The study reported here aimed at secondary prevention by concentrating on damage due to failing equipment. In particular the expansion of the presence of GSM devices has made clear that a new problem is being introduced in health care. The risk of hazardous interference and annoying disturbances in the patient's home and on the streets will increase. Problems can be anticipated for such equipment as infusion devices, complex wheelchairs and oxygen provision at home.

Two contrasting developments can be noted. First, the industry, encouraged by the success of GSM devices, is working on better and faster communication systems. These systems are characterized by higher frequencies; their signals have greater bandwidths and other transmission characteristics than the currently employed systems. Second, there is opposition from the medical technology industry against new standards with more stringent EMC requirements. This resistance aggravates the EMC problems because standards lag behind new developments by definition. Currently applied transmission signals are not yet covered by standard EMC requirements. They still depart from the field strength threshold of 3 V/m although this threshold is exceeded by far by many transmitting stations. The consequences of these contrasting movements could imply higher risks to patients.

2 Execution of the study

In practical conditions at a number of lessors, sources of disturbances were activated in the vicinity of medical equipment. The aim was to test in particular equipment for which safety aspects are relevant as well as equipment that is hired out on a regular basis. A group of apparatuses as representative as possible were tested, allowing for the facilities of the lessors and available time. Measurements were performed in simulated practical conditions because it was essential to have the equipment operate under realistic conditions. Healthy volunteers were used wherever risks were involved that might evoke adverse consequences for patients. For some apparatuses, a technical 'dummy' was used in place of a patient or a healthy volunteer. If required, the participating companies assisted in operating the equipment, which obviously function more simply than intramural equipment.

2.1 Medical equipment at home

The below table presents an overview of the medical equipment examined. The apparatuses were selected in consultation with, among others, organizations that sell or lend out medical equipment. Care was explicitly taken that specific types of equipment were drawn into the tests, wheelchairs included. Details on the equipment tested and their reactions to interference are listed in Appendix A.

INFUSION PUMPS	
General (volumetric, syringe)	**2**
Drug pumps	**8**
Nutritional pumps	**5**
MONITORING *)	**6**
BEDS	
Electrically operated beds	**2**
Patient hoists	**2**
MISCELLANY	
Wheelchairs	**20**
Scooters	**14**
Drug atomizers	**4**
Respiratory support equipment	**12**
Mucus suction device	**1**
Dialysis equipment	**2**
Blood glucose monitors	**14**
Sphygmomanometers	**2**

Social alarm equipment	3
Insulin pens	2
EMG device	1
Total	**100**

*) In this equipment coronary care (ECG or pulse), respiration (motion or RESP) and blood saturation (SpO2) were built in, in varying combinations.

Medical equipment used in ambulances was left out of this study. Obviously, this equipment is also used outside the hospital and is exposed to fields from the same pocket phones as those evaluated in this study. There are reports warning that some of these apparatuses require improvement because they are used, by definition, in emergency situations[12].

Pacemakers and hearing aids were left out of the study for the reasons given above.

2.2 Pocket phones and similar emitting devices

The behaviour of pocket phones as a source of disturbances is only known for intramural use; this aspect is still in the focus of attention across the world (see recent literature[13]). To the best of our knowledge, until this report was finished, no publications have been devoted to the disturbing behaviour of a bigger variety of types of medical equipment in extramural care.

The study focused on the following types of pocket phones and the like:

- GSM 900 MHz 2 W
- GSM 900 MHz 8 W
- DCS 1800 MHz 1 W
- DECT 1900 MHz 0.25 W
- CT 0 40 MHz 0.01 W

These and other systems are described in detail in Appendix B. In that appendix, also figures from the literature are quoted, which illustrate the great extent of penetration of mobile phones. A look ahead until 2015 is also presented in Appendix B. The following explanation suffices here:

[12] Tobisch and Irnich's book, reference [5].

[13] ECRI publication, reference [7].

1) GSM 2 W was involved in the tests because this system is currently used most of all.

2) GSM 8 W was involved because the version with this transmitting power is found in the extramural situation as a mobile (car-bound) device. The GSM 8 W variant was also used to verify the anticipated correlation between likelihood of disturbances and 'transmitting power'.

3) DCS 1800 1 W is strongly expanding. It is also referred to as GSM 1800 because it will replace/extend the GSM system.

4) DECT 0.25 W was involved in the tests because this system has a fair chance of being applied in buildings.

5) CT 0 was included in the tests as an example of a commonly used system with a very low transmitting power, which is expected to hardly induce disturbances.

For an overview covering many more radiotelephone systems, the reader is referred to Appendix B, which describes why many systems were not included in the study.

Walkie-talkies and the like are beyond the scope of this study for the following reason. It was decided to focus on pocket phones that are or soon will be on the market in large numbers. Therefore, walkie-talkies and the like were not included. Security services, porters, fire brigades, police, etc frequently use these devices. Because of the high transmitting power of these devices (from 1 W to 5 W) and because of their permanent presence in the hospital, they carry a great risk of disturbing medical equipment[14] (more than most pocket phones for all types of medical equipment), but their number will not exceed those of pocket phone now or in the near future. Moreover, the users of walkie-talkies and the like (mostly professionals) can rather simply be informed and instructed with regard to disturbance aspects of these tools. For that reason, pocket phones were considered to carry a greater potential risk than walkie-talkies and the like. This was a point of departure for this study. Another reason was that the risk of disturbances by walkie-talkies and the like is not under dispute: it has been an established fact for years (see, for example, a paper published in 1979[15]).

Analogue pocket phones were not included in the study because they are increasingly losing popularity and have not and will not have the high degree of penetration digital pocket phones have. For that reason, the confusing discussion in the

[14] An MDA publication (UK) in 1997 (reference [8]) reports extensively on the influence on medical equipment of 'two-way radios' with a high transmitting power.

[15] Elektronik im Kraftfahrzeug, VDI Berichte 612, Oktober 1986, ISBN 3-18-090612-X, pp. 502-503.

literature about the question whether or not analogue pocket phones lead to more serious disturbances than do digital ones is not relevant any more[16].

In the disturbance tests, various types of pocket phones and the like were used. The following precautions were taken to guarantee that these tests were representative and could proceed smoothly:

GSM:
Two GSM arrangements were used in the study, one of which was designed as a dipole antenna configuration. That arrangement could be adjusted to both 2 W and 8 W. The other simulator had a fixed transmitting power of 2 W. Earlier trials had convincingly shown that the simulation arrangements produced a similar disturbing action as a regular GSM phone. The reason for not using a regular GSM phone was that the GSM network determines whether or not a GSM phone transmits at its maximum power (2 W). For that reason, a GSM phone could not serve as a 'constant source of disturbances' in the disturbance experiments because no reproducible results would be obtained. Reproducible results were achieved indeed with the simulation arrangements.

DCS 1800:
Use was made of a pocket phone set by the manufacturer to the required constant transmitting power (30 dBm = 1 W) through intervention in its electronic circuit.

DECT:
Use was made of a DECT pocket phone with its corresponding base station.

CT 0:
Use was made of a CT 0 pocket phone with its corresponding base station.

2.3 Patterns in the likelihood of disturbances

Relationship between likelihood of interference and transmitting power
It was examined whether more powerful pocket phones cause disturbances at a greater distance than do less powerful ones. Although this relationship seems to be obvious, it is important to explore whether in practice the distance at which interference occurs increases with increasing transmitting power of pocket phones and, if so, what pattern underlies this relationship. The theoretical formula $E = 7(\sqrt{W})/d$ is thus tested against practice. Tests of this nature are useful and are usually conducted. They may yield surprising results. For example, Segal et al. recently found

[16] Tobisch and Irnich's book (reference [5], p. 97) states (erroneously in the opinion of TNO) that analogue phones lead to stronger disturbances and that apparently the average transmitting power determines the risk of disturbances. The draft 2nd edition of standard IEC 60 601-1-2 (reference [10], p. 66) mentions the opposite, namely that digital pocket phones produce stronger disturbances than do analogue ones. This controversy (which is no longer very relevant anyhow) might be solved by means of the two rules of thumb in the next chapter of this report.

that the field strength of pocket phones in hospital rooms does not fit the theoretically expected curve but is higher under specific conditions, and lower under other conditions, than could be expected on the basis of the above 'free field' formula.

Relationship between likelihood of interference and transmission frequency
Another envisaged result of these practical tests was to find a rule of thumb for the frequency dependence of the disturbance threshold. A strong suspicion existed that higher frequencies exert less disturbing actions than lower frequencies. This assumption could be tested by systematically comparing interference phones operating at 1800 MHz with those operating at 900 MHz. The outcome has to be corrected for power differences in order to compare just the effect of differences in transmission frequency.

3 Results of the study

The results are summarized here and described in greater detail in Appendix A.

3.1 Sensitivity of medical equipment at home

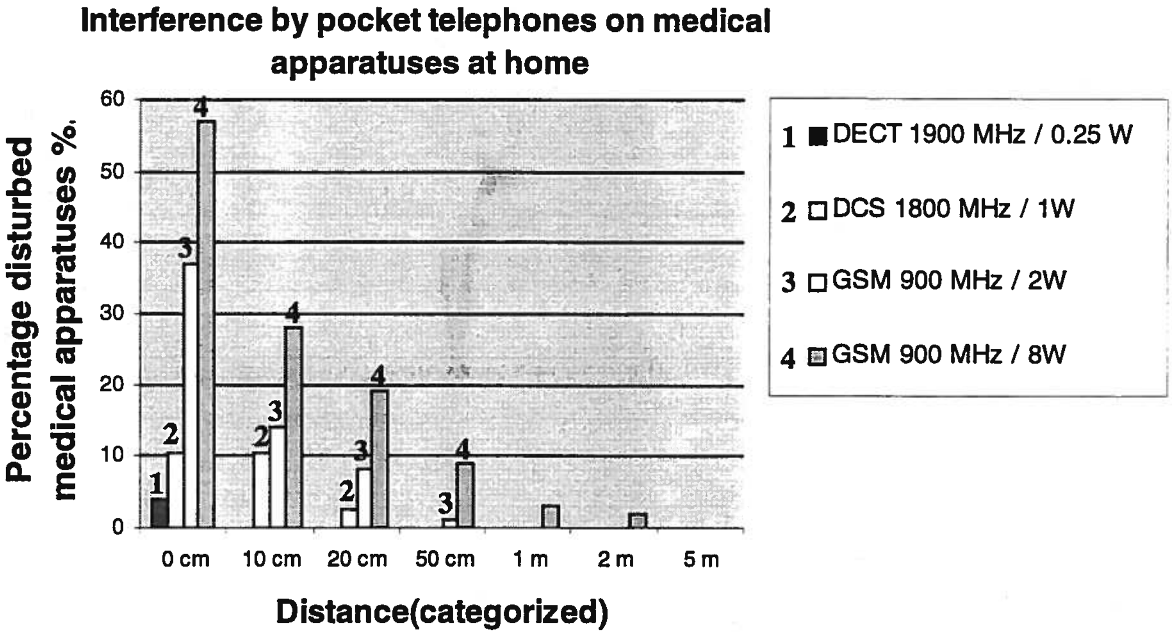
The results showed the following picture of the sensitivity to interference of extramural medical equipment.

Of the 100 medical apparatuses tested, 42 appeared to be immune to all sources of interference applied. The greatest percentage of disturbance occurred with the GSM 8 W source: 57 medical apparatuses appeared to be sensitive. The greatest distance at which interference could occur was 300 cm (respiratory support device). Of the 57 apparatuses sensitive to GSM 8 W, 19 (33%) reacted in a way that could impair safety. Of the 37 apparatuses sensitive to GSM 2 W, 17 (46%) reacted in an unsafe manner. For DCS 1800 the percentage of sensitive apparatuses was 10%, for DECT (1900 MHz) 4%, and for CT 0 (40 MHz) 3%. With all interference sources unsafe reactions occurred as well. These unsafe reactions occurred at all distances, not primarily at the shortest distances. Respiratory support devices belonged to the most sensitive apparatuses and also mostly elicited unsafe reactions. Several other apparatuses were only unsafe at distances of some centimetres until some decimetres (e.g. blood glucose monitors, infusion pump for medicine, social alarm equipment, wheelchairs and scooters). Of the 34 wheelchairs and scooters tested, 13 reacted, but the transmitting antenna of the pocket telephone had to be very close to the electronic circuits of the wheelchair concerned to elicit a reaction.

The below figure summarizes all results and can be clarified as follows. On the horizontal axis the distances are plotted at which interference with medical equipment was observed. The vertical bars indicate what percentage of medical equipment was disturbed at that particular distance or above. For example, 28% of the medical apparatuses tested were disturbed by GSM 900 MHz/8 W at a distance of 10 cm or above. Appendix A presents the results for each source of interference separately (also in tables and in graphs). That appendix also describes in detail the reactions of medical equipment.

Interference of intramural equipment by GSM 900 MHz 2 W has been tested before[17]; 49% of the intramural equipment were found to react. Comparison of these figures with the 37% found in this study for extramural equipment suggests that the extramural equipment tested in the present study is ca. 20% less susceptible to interference by GSM 2 W than the intramural equipment tested previously.

[17] Influence of 2 W GSM pocket phones on 205 medical apparatuses: field measurements. TNO research report TG/95.044. 1 August 1995.(Dutch Language only), Reference [1].



3.2 Rules of thumb for the likelihood of disturbances

The following two empirical rules of thumb reasonably describe the results obtained, as explained below. In the frequency range of 400–1800 MHz the likelihood of interference:

- increases with the square root of the transmitting power (for example, 4-fold higher power results in a 2-fold higher likelihood of interference).
- decreases in an inversely proportional fashion with increasing frequency (for example, when the frequency is doubled, the likelihood is halved).

The data presented in the histogram show that these rules of thumb fairly fit into the interference results found in this study.

According to the first rule of thumb, GSM 8 W would interfere $4^{1/2} = 2$ times as strongly as GSM 2 W. The results (see histogram) show a factor of ca. 1.7.

Comparison of GSM 2 W and DCS 1800/1 W results in the following picture. DCS 1800 transmits with a power of 1 W, 2-fold less than GSM 2 W. Hence (first rule of thumb), the likelihood of interference will be $2^{1/2}$ = ca. 1.4 times lower for DCS 1800 than for GSM 2 W. DCS 1800 transmits with a frequency twice as high as that of GSM, hence (second rule of thumb) the likelihood of interference will be twice as low. The product of these factors is 1.4 x 2 = 2.8. The results show that GSM 2 W and DCS 1800 differed in interference by a factor of ca. 3.5. It should be noted, however, that the number of disturbances by DCS 1800 was small (4 apparatuses), so no smooth curve for this analysis could be obtained.

Appendix A shows that these two rules of thumb also reasonably hold for recent results reported in the literature and for previous results reported by TNO. The first rule of thumb can be readily explained intuitively considering that the field strength is a function proportional to $(P)^{1/2}$. The plausibility of the second rule of thumb is demonstrated in Appendix A.

CAVEAT. These rules of thumb can only be used for policy making after being further tested. It has to be tested, for example, whether the relationship between likelihood of interference and frequency is also inversely proportional for the IMT-2000 system (also referred to as UMTS), as would be expected on the basis of the second rule of thumb. The frequency of IMT-2000 is 2.1 GHz, i.e. far above the range to which the rules of thumb provisionally apply. Moreover, it should be noted that they are rules of thumb indeed, based on the 'average likelihood', so the interference behaviour of a specific medical apparatus may appreciably deviate from these rules of thumb.

3.3 Regulations for extramural equipment

Many hospitals across the world have issued a ban on the use of pocket phones. Obviously, such a ban is meaningless in the extramural situation: the use of pocket phones is more or less fact. The only decision that can be made for the extramural situation is whether or not to issue a warning that the use of pocket phones can cause disturbances. It could also be considered to formulate requirements for medical equipment to be used at home, whether or not on a voluntary basis.

Because a hospital ban on the use of pocket phones is sort of warning signal for the public at large that pocket phones may disturb medical equipment, it is useful to briefly discuss the intramural situation with a view on the extramural situation.

The argument that pocket phones pose no problem because there are no reports of incidents is not very convincing because incidents in general tend to be reported only rarely. Moreover, the disturbances referred to in this report are EMC interference incidents, which are very hard to identify and are usually not recognized by users as an EMC problem. Even if users report an incident, they will report, for example, that the apparatus failed to work but worked again soon after. It may be exactly attributable to the ban on pocket phones in many hospitals that there are few reports of accidents. As an (inadvisable) experiment, one could consider to raise the ban just to see whether incidents would occur. The possibility of disturbances in practice has convincingly been demonstrated to react seriously to them. If one wants to recognize reports, there are incidents indeed, albeit they are not always well documented as disturbances. Finally, another aspect taken into consideration is that many 'harmless' disturbances still may contribute to hazardous situations because the attention of attending personnel is needlessly diverted.

For the intramural situation, ECRI[18] and others state that the restrictive measures described above could be relaxed (but not abolished!). The ECRI advice is based, partly on Irnich and Tobisch[19]. The following points relevant to the extramural situation as well can be derived from Irnich and Tobisch findings:

- At distances ≥1 m, 10 out of 224 (predominantly intramural) medical apparatuses (4.5%) were sensitive to interference by pocket phones with a transmitting power of 0.5 W and a transmission frequency of 450 MHz.

  Note: ECRI analysed data from Irnich and Tobisch incorrectly, quoting that of the 224 apparatuses, 4 (2%) were affected at distances greater than 1 m. The number of 4 mentioned by Irnich and Tobisch referred just to the apparatuses that underwent 'realistic dangerous' interference; taking 'realistic dangerous' and 'harmless' disturbances together, Irnich and Tobisch found 10 disturbed apparatuses. This confusion was verified with the authors (see also the next item).

- For 4 of the 10 apparatuses, the interference was qualified as 'realistic dangerous'. In other words, for these 4 apparatuses, the susceptibility to interference by 0.5 W/450 MHz pocket phones was 'realistic dangerous' at a distance of ≥1 m. Two of these 4 apparatuses were apnoea monitors.
- At a distance of ≥1 m, 5 of the 224 apparatuses (2.2%) were sensitive to pocket phones with a transmitting power of 2 W and a transmission frequency of 900 MHz. The interference was not hazardous for any of these 5 apparatuses.

3.4 Apnoea monitors

A special aspect of some apnoea monitors is that the monitors detect electromagnetically whether the patient is still breathing. The monitors must not warn when there is a slowly varying electromagnetic signal really representative of the respiratory rhythm. In some apnoea monitors, the alarm in case of apnoea could be suppressed when a pocket phone was slowly moved up and down. Hence, when the patient does not breath any more and there is still a slowly varying electromagnetic signal induced by a pocket phone, such monitors do not alert as they should do.

In this study, two of the apnoea monitors tested proved to be sensitive at a distance of ≤50 cm (Nos. 6 and 7 in the table in Appendix A). Both reacted in a hazardous manner, at a distance of 5 cm and 50 cm respectively.

Tobisch and Irnich[20] tested four apnoea monitors, all of which reacted, for example to GSM 900 MHz 8 W at distances of 400, 200, 200 and 50 cm. Three monitors were qualified as 'hazardous', (See the table in Appendix D derived from Tobisch and Irnich's book.)

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[18] ECRI publication 1999, reference [7].

[19] Paper 'Mobile phones in hospitals', January/February, reference [6].

[20] Tobisch en Irnich's book, reference [5].

3.5 Wheelchairs

Users of electrical wheelchairs should be warned in the instructions for use that, as a precaution, they better switch off their wheelchair before using a mobile phone. Such warnings are already common practice. The 'separation distance' prescribed in the 2nd edition of IEC 60 601-1-2 should be specified as well. Sensitive electronics should not be present on places on which luggage can be transported in the wheelchair because luggage may encompass a pocket phone which is in contact with the network and can be called up, thus potentially exerting a disturbing action. For wheelchairs that are fully unsusceptible, it should be mentioned to what pocket phones this applies (as to power and frequency; see examples in Appendix C).

3.6 Warnings for pocket phones

The Internet site http://www.gsmworld.com/technology/tech_faq.html alerts to the potential influence of pocket phones on medical equipment as follows (the last sentence refers to the medical equipment in the domestic situation):

> ***Why are there so many restrictions on using mobile phones in hospitals?*** At short range, the radio signal from a mobile phone may cause interference with electronic medical devices. At distances greater than 2 m the possibility is substantially reduced. It is possible for mobile phones to be used in designated areas of hospitals; however, you should obey any warning signs and the instructions of hospital staff. If you use electrical medical equipment in your home, we recommend that you seek the advice of your doctor or equipment supplier.
>
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> GSM Association world wide web site address:
> http://www.gsmworld.com/

3.7 Warnings for medical equipment

In the draft second edition of IEC 60 601-1-2, the EMC standard for medical equipment, a number of requirements are formulated that did not apply yet in the first edition. For example, the documentation of medical equipment shall specify the 'separation distance' to pocket phones of a specified power. Pocket phones should not be closer than that distance to medical equipment. The separation distance must be specified by means of a formula in which the power of the pocket phone can be filled in. If users know the transmitting power of a pocket phone, they can calculate at what distance from the equipment it may be used. It seems to be an improvement compared to the first edition of the standard because this amendment solves the problem of specification of the sensitivity to interference of new equipment. Experience must learn whether it works out satisfactorily in daily practice. The draft second edition takes 2.5 GHz as the highest frequency with the argument that, for the time being, few sources of interference will operate at frequencies higher than that. The draft second edition of IEC 60 601-1-2 explains that the modulation method is to be chosen on the basis of the properties of the apparatus to be tested. If that apparatus registers very low frequencies, for example, the field of interference should be modulated with those very low frequencies.

Moreover, the draft second edition requires an immunity threshold of 10 V/m for vital equipment, called 'life-supporting equipment' in the draft. For other equipment (including much of the equipment for home care), the threshold remains 3 V/m. The 'separation distance' is based on this threshold of 3 or 10 V/m. However, specific standards apply for specific medical apparatuses with other field strengths, including wheelchairs.

By introducing the 'separation distance', the draft second edition passes over the fact that about half of all medical equipment is insensitive to interference by pocket phones, even if the antenna is held against that medical equipment, i.e. at a 'separation distance' of 0 cm. This shortcoming in the draft could be simply circumvented by claiming explicitly in the manual for such equipment that it is insensitive to the electromagnetic fields of pocket phones. For equipment for which a situation in which a pocket phone is held against it is real (for wheelchairs, for example), this appears to be a recommendable option. On the other hand, it may be advisable to make some reservation for equipment for which the close proximity of a pocket phone is not a likely situation by specifying a minimal separation distance in the manual even if the equipment is fully insensitive to interference.

4 Conclusion

Results summarized

Medical equipment at home is comparably sensitive to fields from pocket telephones as medical equipment in the hospital: within 1 to 2 m, interference can occur. Therefore a warning about the sensitivity of extramural equipment to interference remains to be justified. On the other hand, too much fear for influences of this type is needless. No indications were found for wheelchairs being disturbed by pocket phones carried by passers-by; however, for the sake of security, users of wheelchairs who want to use a hand-held telephone themselves should first switch off their wheelchair. Foreign publications indicate that apnoea monitors must be made less sensitive if this has not been done yet. Warnings against possible interference must be added to pocket telephones and be placed on the Internet (in most cases this already happens on the basis of publications from 1995). Warnings should be added to medical equipment as well.

The new draft second edition of the EMC standard for medical equipment (applicable from around 2001) prescribes manufacturers of medical equipment to specify at how close distances near medical equipment mobile communication devices may be used in relation to their transmitted power. It is therefore necessary that manufacturers of pocket phones and the like indicate this power and that they indicate it as <u>maximum</u> power. Annex C to this report gives examples of this.

Warnings

The new DCS 1800 system results in few interferences. The overall conclusion is that medical equipment for home use is slightly less sensitive to interference than medical equipment in the hospital. However, outside the hospital stronger sources of interference are to be expected, such as vehicles close to the window, and no professional personnel is available if interference problems occur. Therefore, a serious warning statement should be addressed to both manufacturers of pocket phones and producers of medical equipment. That warning statement is that, on the one hand, medical equipment for home use must be made less sensitive to disturbing fields emitted by pocket phones and, on the other, manufacturers of pocket phones should (continue to) include warnings with the phones and on the Internet against using these phones near medical equipment. Medical apparatuses must be accompanied by a warning against possible interference influences. A more or less reassuring conclusion from the investigation is that no high sensitivities were found for wheelchairs: some wheelchairs were sensitive but only if the antenna of the transmitting device was brought very close to the electronic circuits of these wheelchairs.

Unless manufacturers of wheelchairs fully guarantee the insensitivity of their products, wheelchair users should bring their wheelchair in a safe situation (switch it off) before they make phone calls themselves. The results of this study do not indicate that pocket phones that are at a distance of more than a few decimetres, for example in the hands of passers-by, do disturb wheelchairs.

5 Signatures

Author(s)	Signature
R. Hensbroek, M.Sc. Manager, Safety and EMC	Was signed

Internal evaluation by	Signature
R.G.M. van Melick, Pharm.D. Manager Testing and Inspections	Was signed

Appendix A Behaviour of the equipment tested

This appendix describes all reactions of the medical equipment tested. The distance at which the reactions occurred is also mentioned. Finally, the results found are analysed.

A.1 All results in one table

The table on the next pages summarizes all results of the study: all apparatuses tested are listed as well as the sources of interference applied. For every medical apparatus tested and for each source of interference applied, the interfering effects are mentioned. The table mentions the distance from the transmitting antenna <u>in centimeters</u> at which the disturbance described in the footnotes occurred. No interference at all is indicated by an **n** (for no interference). A dash (–) in the table means that the equipment in question was not tested against that particular source of interference. Disturbances giving rise in practice to an unsafe situation is indicated by an **U** (for unsafe). Footnotes describe the nature of the disturbance in further detail.

<u>Note</u>: If no interference occurred, the test was obviously also performed at a distance of 0 cm; however, because there was no interference, no distance is mentioned. As a matter of course, if interference was only found at a distance of 0 cm, **'0 cm'** is mentioned.

<u>Note</u>: If interference only occurred at a short distance from the apparatus tested (relative to the dimensions of the apparatus), the site on the apparatus at which interference occurred during the study was recorded as well. For brevity sake, however, that site has not been included in this report.

<u>Note</u>: The footnotes apply to all influences found on the equipment as listed in every row of the table. In the few cases that the influences differed among sources of interference, multiple footnotes refer to that row, i.e. one footnote for each source involved.

No.	Medical equipment	GSM sim 2 W	GSM dipole 2 W	GSM dipole 8 W	DCS 1800 1 W	DECT 0.25 W	CT 0 0.01 W
1	Respiration/H_2O[1]	20 cm: U	20 cm: U	50 cm: U	–	n	n
2	Respiration/H_2O[2]	30 cm: U	30 cm: U	200 cm: U	–	n	n
3	Respiration/H_2O[3]	30 cm: U	2 cm: U	10 cm: U	–	n	n
4	Respiration/H_2O[4]	20 cm: U	20 cm: U	100 cm: U	–	n	0 cm: U
5	Respiration/H_2O[5]	50 cm: U	100 cm: U	300 cm: U	–	0 cm: U	10 cm: U
6	Respiration monitoring[6]	n	n	5 cm: U	–	n	n
7	Respiration monitoring[7]	0 cm: U	10 cm: U	50 cm: U	–	n	n
8	Monitoring SpO_2[8]	n	n	0 cm	–	n	n
9	Monitoring SpO_2/ respiration	n	n	n	–	n	n
10	Monitoring SpO_2 / respiration	n	n	n	–	n	n
11	Monitoring SpO_2 / respiration[9]	0 cm: U	0 cm: U	10 cm: U	–	n	n
12	Sphygmomano-meter[10]	n	n	5 cm	n	n	n
13	Sphygmomano-meter	n	n	n	n	n	n
14	Blood glucose meter	3 cm[11]	3 cm: U[12]	30 cm[13]	–	n	n
15	Blood glucose meter	30 cm: U[14]	20 cm[15]	55 cm[16]	10 cm[17]	n	n
16	Blood glucose meter[18]	1 cm	1 cm	10 cm	–	n	n
17	Blood glucose meter[19]	n	n	3 cm	–	n	n
18	Blood glucose meter[20]	3 cm	n	n	–	n	n
19	Blood glucose meter[21]	5 cm	5 cm	5 cm	–	n	n

[1] Very brief or no alarm; functioning is affected.
[2] Very brief or no alarm; functioning is affected.
[3] Very brief or no alarm; functioning is affected.
[4] Very brief or no alarm; functioning is affected.
[5] Very brief or no alarm; functioning is affected.
[6] No alarm in the presence of a moving pocket phone.
[7] Very brief or no alarm; functioning is affected.
[8] Acoustic and/or visual alarm; functioning or set-up is influenced; switching off and on usually required.
[9] Functioning disturbed; alarm is not switched on.
[10] No measurement; error message on display.
[11] Error message or display disturbed; user has to repeat the measurement.
[12] Faulty measured value.
[13] Error message or display disturbed; user has to repeat the measurement.
[14] Faulty measured value.
[15] Error message or display disturbed; user has to repeat the measurement.
[16] Error message or display disturbed; user has to repeat the measurement.
[17] Error message or display disturbed; user has to repeat the measurement.
[18] Error message or display disturbed; user has to repeat the measurement.
[19] Error message or display disturbed; user has to repeat the measurement.
[20] Error message or display disturbed; user has to repeat the measurement.
[21] Error message or display disturbed; user has to repeat the measurement.

No.	Medical equipment	GSM sim 2 W	GSM dipole 2 W	GSM dipole 8 W	DCS 1800 1 W	DECT 0.25 W	CT 0 0.01 W
20	Blood glucose meter[22]	10 cm	10 cm	40 cm	–	n	n
21	Blood glucose meter[23]	10 cm	10 cm	50 cm	–	2 cm	n
22	Blood glucose meter[24]	3 cm	2 cm	5 cm	–	n	n
23	Blood glucose meter[25]	3 cm	3 cm	8 cm	–	n	n
24	Blood glucose meter[26]	5 cm	5 cm	10 cm	–	n	n
25	Blood glucose meter[27]	5 cm	n	12 cm	–	n	n
26	Blood glucose meter[28]	n	n	3 cm	–	n	n
27	Blood glucose meter [29]	n	n	10 cm	–	n	n
28	Dialysis device	n	n	n	–	n	n
29	Dialysis device[30]	10 cm	10 cm	25 cm	–	0 cm	n
30	EMG device	n	n	n	n	n	n
31	Elec.operated bed[31]	0 cm	0 cm	15 cm	n	n	n
32	Elec.operated bed[32]	0 cm	0 cm	30 cm	n	n	n
33	Infusion pump	n	0 cm[33]	5 cm[34]	–	n	n
34	Infusion pump[35]	10 cm	10 cm	30 cm	–	0 cm	n
35	Infusion pump (drugs)	n	n	n	–	n	n
36	Infusion pumps (drugs)	n	n	n	–	n	n
37	Infusion pump (drugs)	n	n	n	–	n	n
38	Infusion pump (drugs)	n	n	n	–	n	n
39	Infusion pump (drugs)	n	n	n	–	n	n
40	Infusion pump (drugs)[36]	n	n	5 cm	–	n	n
41	Infusion pump (drugs)[37]	n	n	0 cm	–	n	n

[22] Error message or display disturbed; user has to repeat the measurement.
[23] Error message or display disturbed; user has to repeat the measurement.
[24] Error message or display disturbed; user has to repeat the measurement.
[25] Error message or display disturbed; user has to repeat the measurement.
[26] Error message or display disturbed; user has to repeat the measurement.
[27] Error message or display disturbed; user has to repeat the measurement.
[28] Error message or display disturbed; user has to repeat the measurement.
[29] Error message or display disturbed; user has to repeat the measurement.
[30] Functioning stops; acoustic + visual alarm + error message; equipment has to be switched off and on and readjusted/restarted.
[31] No longer operable; acoustic alarm.
[32] No longer operable; no alarm, but a relay is flapping audibly.
[33] False alarm; functioning unaffected.
[34] Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.
[35] Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.
[36] Functioning stops; acoustic + visual alarm + error message; equipment has to be switched off and on and readjusted/restarted.

No.	Medical equipment	GSM sim 2 W	GSM dipole 2 W	GSM dipole 8 W	DCS 1800 1 W	DECT 0.25 W	CT 0 0.01 W
42	Infusion pump (drugs)[38]	n	n	5 cm: U	–	n	n
43	Insulin pen	n	n	n	n	n	n
44	Insulin pen	n	n	n	n	n	n
45	Humidifier[39]	n	n	5 cm	–	n	n
46	Drug atomizer	n	n	n	–	n	n
47	Drug atomizer	n	n	n	–	n	n
48	Drug atomizer[40]	n	n	10 cm	–	n	n
49	Drug atomizer[41]	n	n	0 cm	–	n	n
50	Patient hoist	n	n	n	n	n	n
51	Patient hoist	n	n	n	n	n	n
52	Social alarm equipment[42]	20 cm: U	30 cm: U	35 cm: U	15 cm: U	n	n
53	Social alarm equipment[43]	20 cm: U	20 cm: U	30 cm: U	10 cm: U	n	n
54	Social alarm equipment[44]	40 cm: U	20 cm: U	50 cm: U	30 cm: U	n	n
55	Wheelchair	n	n	n	–	n	n
56	Wheelchair	n	1 cm[45]	2 cm: U[46]	–	n	n
57	Wheelchair	n	n	n	n	n	n
58	Wheelchair	n	n	n	n	n	n
59	Wheelchair	n	n	n	n	n	n
60	Wheelchair	n	n	n	n	n	n
61	Wheelchair	n	n	n	n	n	n
62	Wheelchair	n	n	n	n	n	n
63	Wheelchair	0 cm[47]	0 cm[48]	5 cm: U[49]	n	n	n
64	Wheelchair	n	n	n	n	n	n
65	Wheelchair	n	n	n	n	n	n
66	Wheelchair	n	n	n	n	n	n
67	Wheelchair	n	n	n	n	n	n

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[37] Functioning stops; acoustic + visual alarm + error message; equipment has to be switched off and on and readjusted / restarted.
[38] Very brief alarm or no alarm; functioning is affected.
[39] Display is disturbed; equipment produces a bleep and readjusts itself; functioning is not impaired.
[40] Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.
[41] Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.
[42] No talking/listening connection due to a strong buzz. When the disturbance is made undone, the aid station is called after all.
[43] No talking/listening connection due to a strong buzz. When the interference source is taken away.
[44] No talking/listening connection due to a strong buzz.
[45] Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
[46] Brakes are released in the standstill position.
[47] Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
[48] Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
[49] Strong increase in speed and/or change of direction.

No.	Medical equipment	GSM sim 2 W	GSM dipole 2 W	GSM dipole 8 W	DCS 1800 1 W	DECT 0.25 W	CT 0 0.01 W
68	Wheelchair	n	n	n	n	n	n
69	Wheelchair[50]	n	n	3 cm: U	–	n	n
70	Wheelchair[51]	n	n	1 cm	–	n	n
71	Wheelchair [52]	n	n	1 cm	-	n	n
72	Wheelchair [53]	n	n	2 cm: U	-	n	n
73	Wheelchair[54]	1 cm	2 cm	5 cm	–	n	n
74	Wheelchair [55]	n	n	2 cm	–	n	n
75	Scooter	n	n	n	n	n	n
76	Scooter	n	n	n	n	n	n
77	Scooter	n	n	n	n	n	n
78	Scooter	n	n	n	n	n	n
79	Scooter	n	n	n	n	n	n
80	Scooter	n	n	n	n	n	n
81	Scooter	5 cm: U[56]	5 cm[57]	20 cm: U[58]	n	n	n
82	Scooter	n	n	n	n	n	n
83	Scooter	n	n	n	n	n	n
84	Scooter	5 cm: U[59]	5 cm[60]	5 cm: U[61]	n	n	n
85	Scooter[62]	1 cm	1 cm	1 cm	n	n	n
86	Scooter[63]	n	2 cm: U	15 cm: U	n	n	n
87	Scooter[64]	n	0 cm: U	25 cm: U	n	n	n
88	Scooter[65]	n	n	0 cm	n	n	n
89	Mucus suction device (nasal tube)	n	n	n	–	n	n
90	Pump (nutrition)	n	n	n	–	n	n
91	Pump (nutrition)[66]	n	n	0 cm	–	n	n
92	Pump (nutrition)[67]	n	n	0 cm	–	n	n
93	Pump (nutrition)[68]	0 cm	0 cm	0 cm	–	n	n

50 Strong increase in speed and/or change of direction.
51 Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
52 Slight speed reduction and/or influence on lights, direction indicator or other indicators for the user.
53 Motor stops.
54 Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
55 Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
56 Strong increase in speed or change of direction.
57 Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
58 Strong increase in speed or change of direction.
59 Strong increase in speed or change of direction.
60 Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
61 Strong increase in speed or change of direction.
62 Slight speed reduction and/or influence on lights, direction indicator or indicators for the user.
63 Strong increase in speed or change of direction.
64 Strong increase in speed or change of direction.
65 A relay connects; no consequences for the user.
66 Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.
67 Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.
68 Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.

No.	Medical equipment	GSM sim 2 W	GSM dipole 2 W	GSM dipole 8 W	DCS 1800 1 W	DECT 0.25 W	CT 0 0.01 W
94	Pump (nutrition)[69]	n	n	0 cm	–	n	N
95	O_2 concentrator	n	n	n	–	n	n
96	O_2 concentrator	n	n	n	–	n	n
97	O_2 concentrator	n	n	n	–	n	n
98	O_2 concentrator	n	n	n	–	n	n
99	O_2 concentrator[70]	0 cm	5 cm	20 cm	–	n	n
100	O_2 concentration meter[71]	15 cm	15 cm	50 cm	–	n	15 cm

[69] Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.
[70] Acoustic and/or visual alarm; functioning or adjusting is influenced; switching off and on usually required.
[71] Display is disturbed.

A.2 Results ordered per source of interference by distance at which the reaction occurred

In this section all medical apparatuses tested are ordered by source of interference and by the distance at which a reaction was found. Like in the above collective table, an 'n' indicates that the equipment did not react at all. Each of the below tables is a copy of one column of the collective table. In the tables the apparatuses are ranked by distance at which an influence was found, with the most susceptible apparatus ranking first. For example, apparatuses 5 and 2 were the most sensitive to both GSM 2 W and GSM 8 W (see the collective table above). Therefore, these apparatuses rank first in the below tables for GSM 2 W and GSM 8 W ranked by their interference distance. The numbers in the third column indicate how many apparatuses reacted at or above the particular distance mentioned in the second column. These numbers are also presented graphically below the tables. The graphs fully represent the results listed in the corresponding tables. The exponential curves are the best-fitting curve through the bars, with the digits 0, 1, 2, 3, 4, 5 and 6 being taken to represent the respective distances on the horizontal axis: for example, the '0 cm' bar corresponds with exp(0). The exponential curves are merely illustrative, for visual support, and were not used for calculations.

GSM 900 MHz/2 W

For GSM 2 W, the average distance for the two applied simulators was taken, i.e. the 2 W GSM simulator and the 2 W GSM dipole. The distances were practically equal for the two simulators. The (small) differences found are shown in the first two columns of the collective table above.

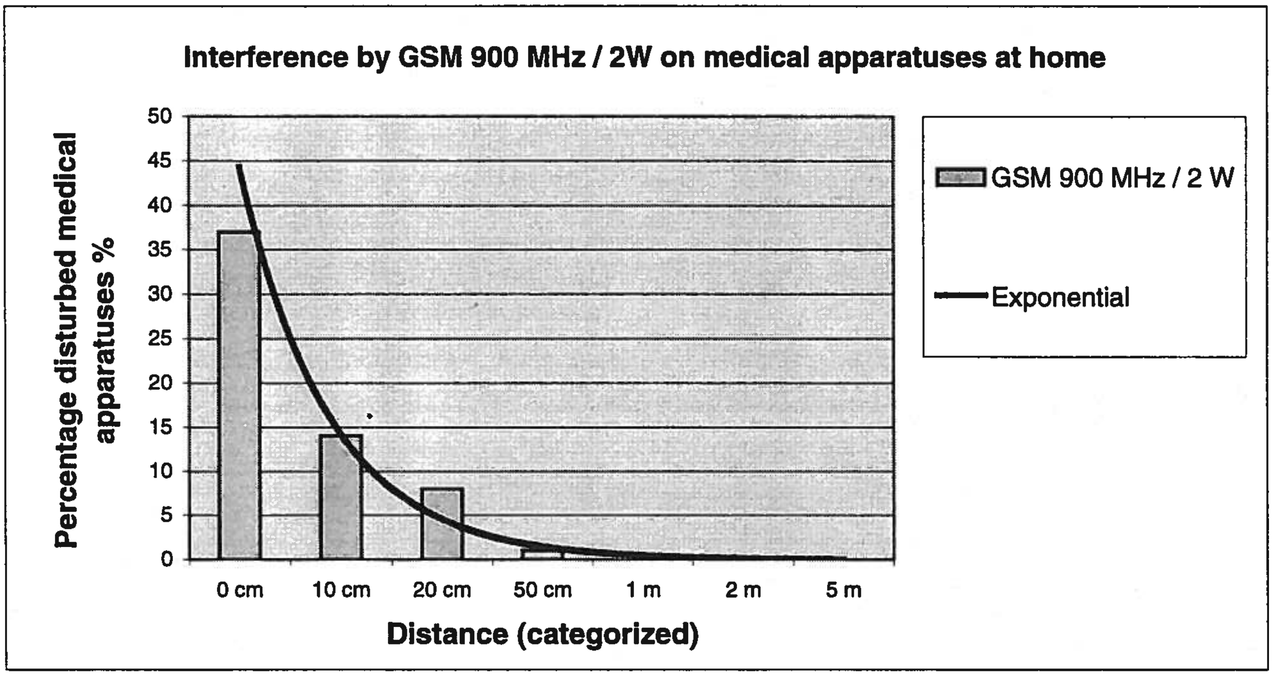
GSM
900 MHz/2 W

5	75 cm: U	1
2	30 cm: U	
54	30 cm: U	
15	25 cm: U	
52	25 cm: U	
1	20 cm: U	
4	20 cm: U	
53	20 cm: U	8
3	15 cm: U	
100	15 cm	
20	10 cm	
21	10 cm	
29	10 cm	
34	10 cm	14
7	5 cm: U	
19	5 cm	
24	5 cm	
25	5 cm	
81	5 cm: U	
84	5 cm: U	
14	3 cm	
18	3 cm	
22	3 cm	
23	3 cm	
99	3 cm	

73	2 cm	
86	2 cm: U	
16	1 cm	
56	1 cm	
85	1 cm	
11	0 cm: U	
31	0 cm: U	
32	0 cm: U	
33	0 cm	
63	0 cm	
87	0 cm: U	
93	0 cm	37
6	n	
8	n	
9	n	
10	n	
12	n	
13	n	
17	n	
26	n	
27	n	
28	n	
30	n	
35	n	
36	n	

37	n	
38	n	
39	n	
40	n	
41	n	
42	n	
43	n	
44	n	
45	n	
46	n	
47	n	
48	n	
49	n	
50	n	
51	n	
55	n	
57	n	
58	n	
59	n	
60	n	
61	n	
62	n	
64	n	
65	n	
66	n	

67	n	
68	n	
69	n	
70	n	
71	n	
72	n	
74	n	
75	n	
76	n	
77	n	
78	n	
79	n	
80	n	
82	n	
83	n	
88	n	
89	n	
90	n	
91	n	
92	n	
94	n	
95	n	
96	n	
97	n	
98	n	



GSM 900 MHz/8 W

GSM
900 MHz/8 W

5	300 cm: U	
2	200 cm: U	2
4	100 cm: U	3
15	55 cm	
1	50 cm: U	
7	50 cm: U	
21	50 cm	
54	50 cm: U	
100	50 cm	9
20	40 cm	
52	35 cm: U	
14	30 cm	
32	30 cm	
34	30 cm	
53	30 cm: U	
29	25 cm	
87	25 cm: U	
81	20 cm: U	
99	20 cm	19
31	15 cm	
86	15 cm: U	
25	12 cm	
3	10 cm: U	
11	10 cm: U	
16	10 cm	

24	10 cm	
27	10 cm	
48	10 cm	28
23	8 cm	
6	5 cm	
19	5 cm	
22	5 cm	
33	5 cm	
40	5 cm	
42	5 cm: U	
45	5 cm	
73	5 cm	
63	5 cm: U	
84	5 cm: U	
12	5 cm	
17	3 cm	
26	3 cm	
69	3 cm: U	
56	2 cm: U	
72	2 cm: U	
74	2 cm	
70	1 cm	
71	1 cm	
85	1 cm	
8	0 cm	

41	0 cm	
49	0 cm	
88	0 cm	
91	0 cm	
92	0 cm	
93	0 cm	
94	0 cm	57
9	n	
10	n	
13	n	
18	n	
28	n	
30	n	
35	n	
36	n	
37	n	
38	n	
39	n	
43	n	
44	n	
46	n	
47	n	
50	n	
51	n	
55	n	

57	n	
58	n	
59	n	
60	n	
61	n	
62	n	
64	n	
65	n	
66	n	
67	n	
68	n	
75	n	
76	n	
77	n	
78	n	
79	n	
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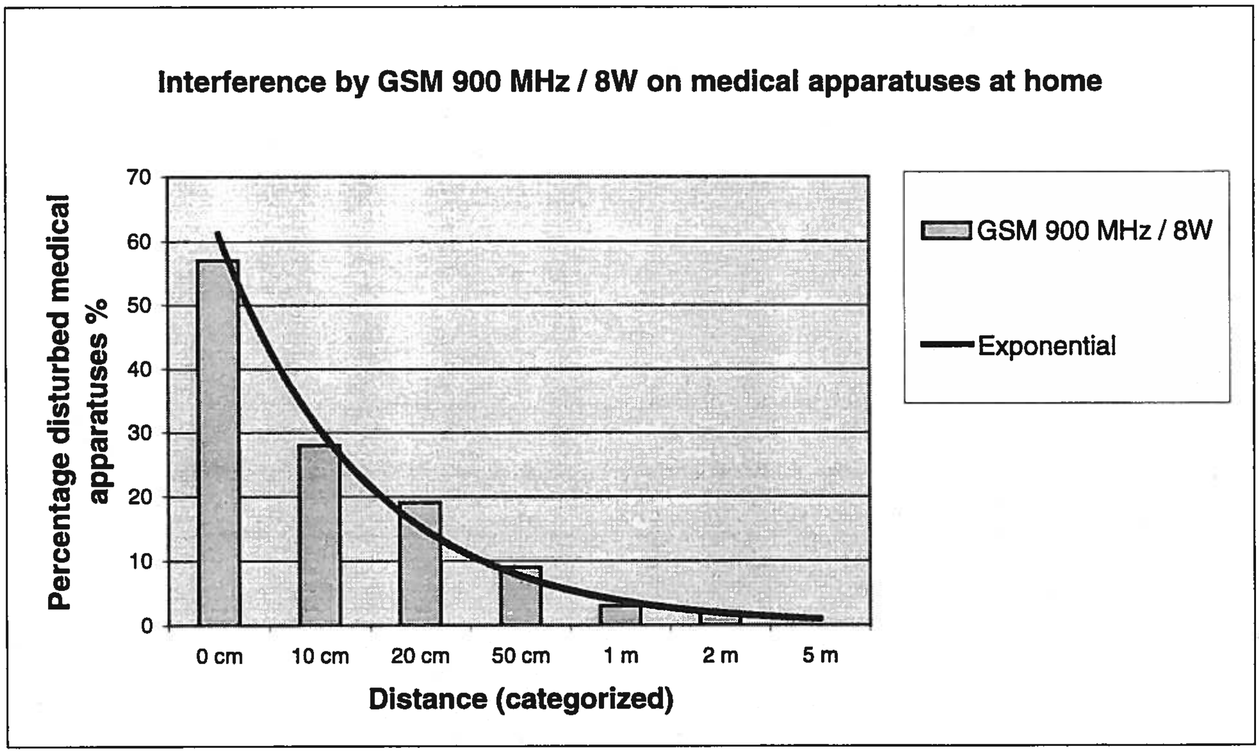
96	n	
97	n	
98	n	



DCS 1800 MHz/1 W

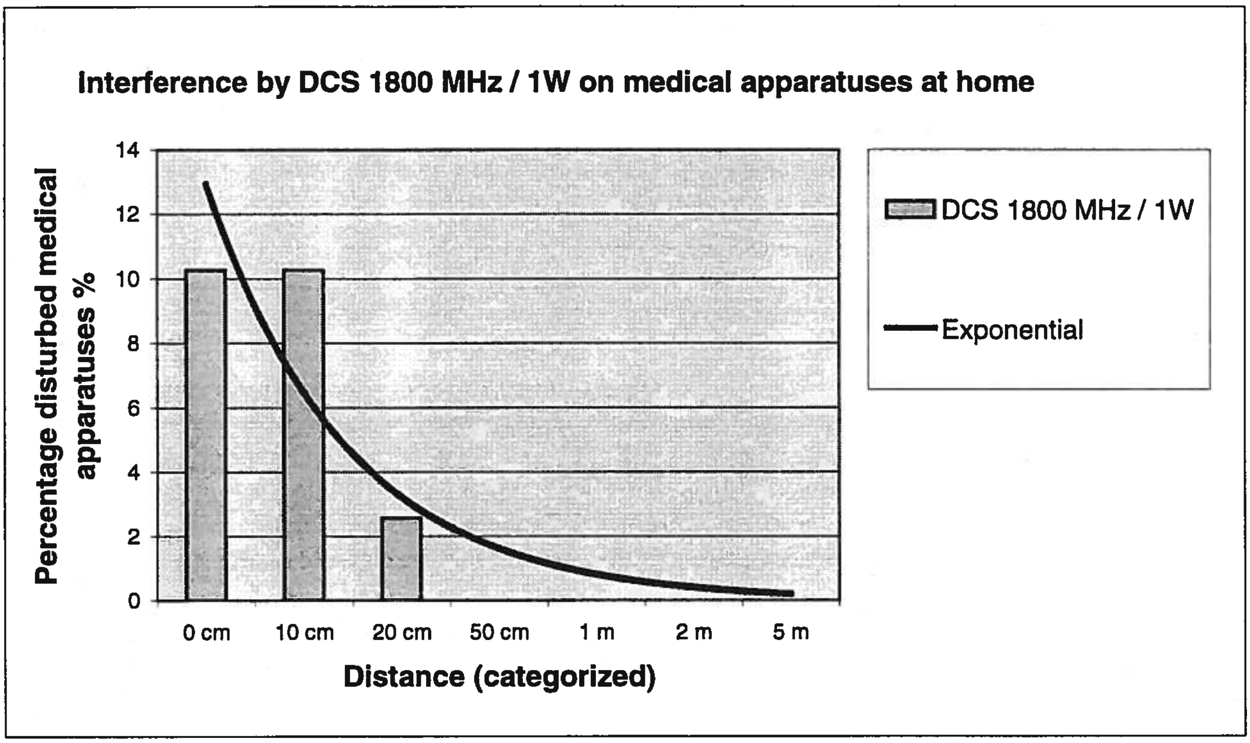
DCS 1800
1800 MHz/1 W

54	30 cm: U
52	15 cm: U
15	10 cm
53	10 cm: U
12	n
13	n
30	n
31	n
32	n
43	n

44	n
50	n
51	n
57	n
58	n
59	n
60	n
61	n
62	n
63	n

64	n
65	n
66	n
67	n
68	n
75	n
76	n
77	n
78	n
79	n

80	n
81	n
82	n
83	n
84	n
85	n
86	n
87	n
88	n



DECT 1900 MHz/0.25 W

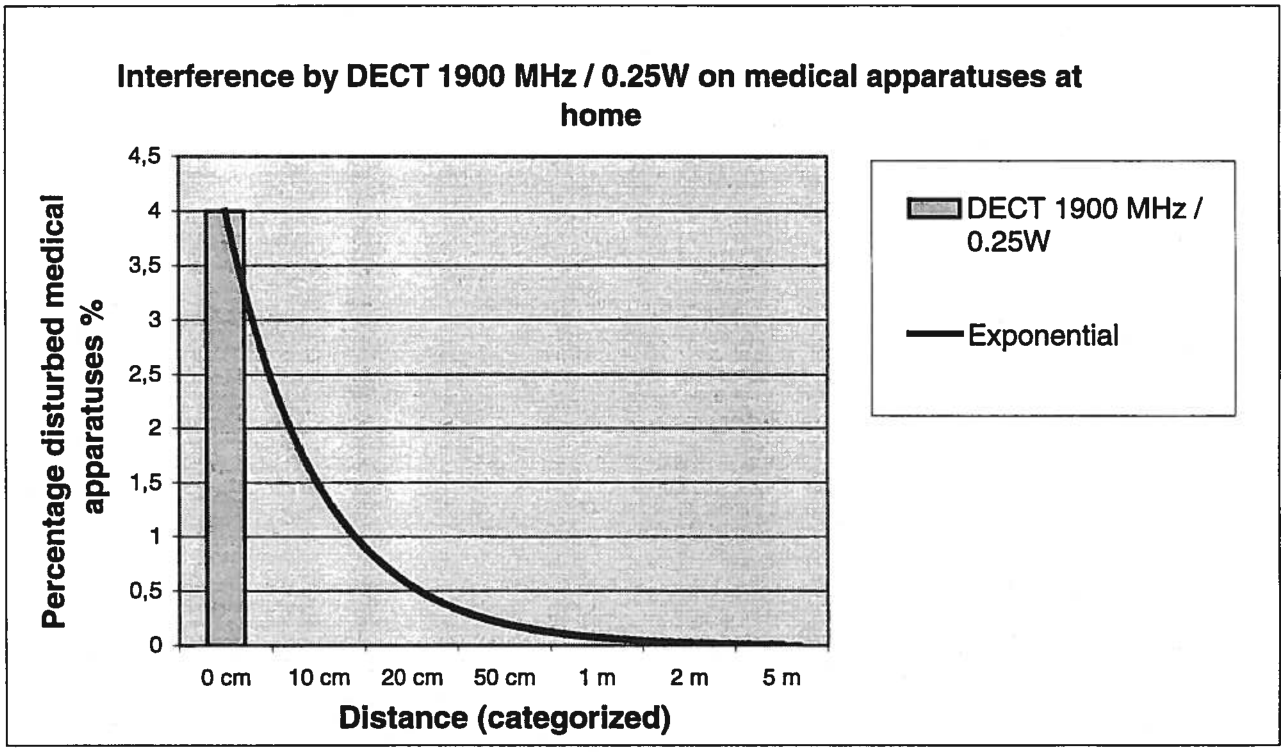
DECT
1900 MHz/0.25 W

21	2 cm
5	0 cm: U
29	0 cm
34	0 cm
1	n
2	n
3	n
4	n
6	n
7	n
8	n
9	n
10	n
11	n
12	n
13	n
14	n
15	n
16	n
17	n
18	n
19	n
20	n
22	n
23	n

24	n
25	n
26	n
27	n
28	n
30	n
31	n
32	n
33	n
35	n
36	n
37	n
38	n
39	n
40	n
41	n
42	n
43	n
44	n
45	n
46	n
47	n
48	n
49	n
50	n

51	n
52	n
53	n
54	n
55	n
56	n
57	n
58	n
59	n
60	n
61	n
62	n
63	n
64	n
65	n
66	n
67	n
68	n
69	n
70	n
71	n
72	n
73	n
74	n
75	n

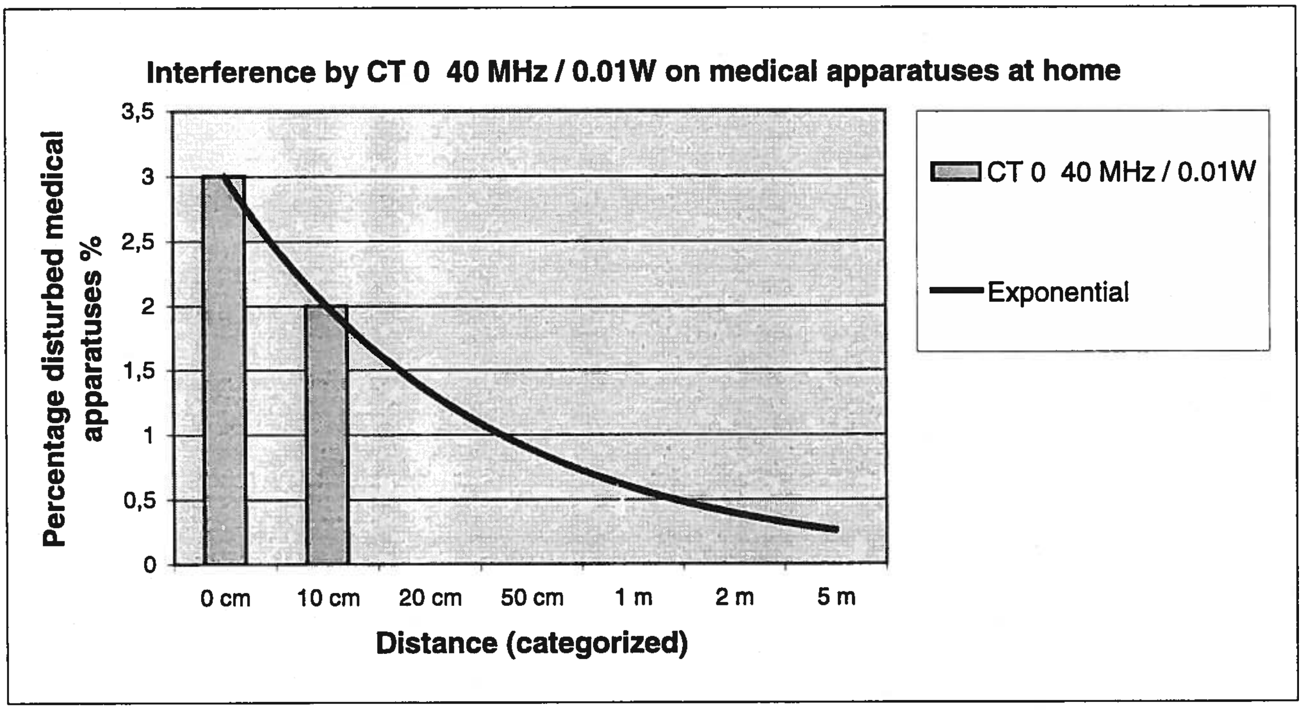
76	n
77	n
78	n
79	n
80	n
81	n
82	n
83	n
84	n
85	n
86	n
87	n
88	n
89	n
90	n
91	n
92	n
93	n
94	n
95	n
96	n
97	n
98	n
99	n
100	n



CT 0 40 MHz/0.01 W

CT 0
40 MHz/0.01 W

100	15 cm	25	n	50	n	75	n
5	10 cm: U	26	n	51	n	76	n
4	0 cm: U	27	n	52	n	77	n
1	n	28	n	53	n	78	n
2	n	29	n	54	n	79	n
3	n	30	n	55	n	80	n
6	n	31	n	56	n	81	n
7	n	32	n	57	n	82	n
8	n	33	n	58	n	83	n
9	n	34	n	59	n	84	n
10	n	35	n	60	n	85	n
11	n	36	n	61	n	86	n
12	n	37	n	62	n	87	n
13	n	38	n	63	n	88	n
14	n	39	n	64	n	89	n
15	n	40	n	65	n	90	n
16	n	41	n	66	n	91	n
17	n	42	n	67	n	92	n
18	n	43	n	68	n	93	n
19	n	44	n	69	n	94	n
20	n	45	n	70	n	95	n
21	n	46	n	71	n	96	n
22	n	47	n	72	n	97	n
23	n	48	n	73	n	98	n
24	n	49	n	74	n	99	n



A.3 Analysis of previous results

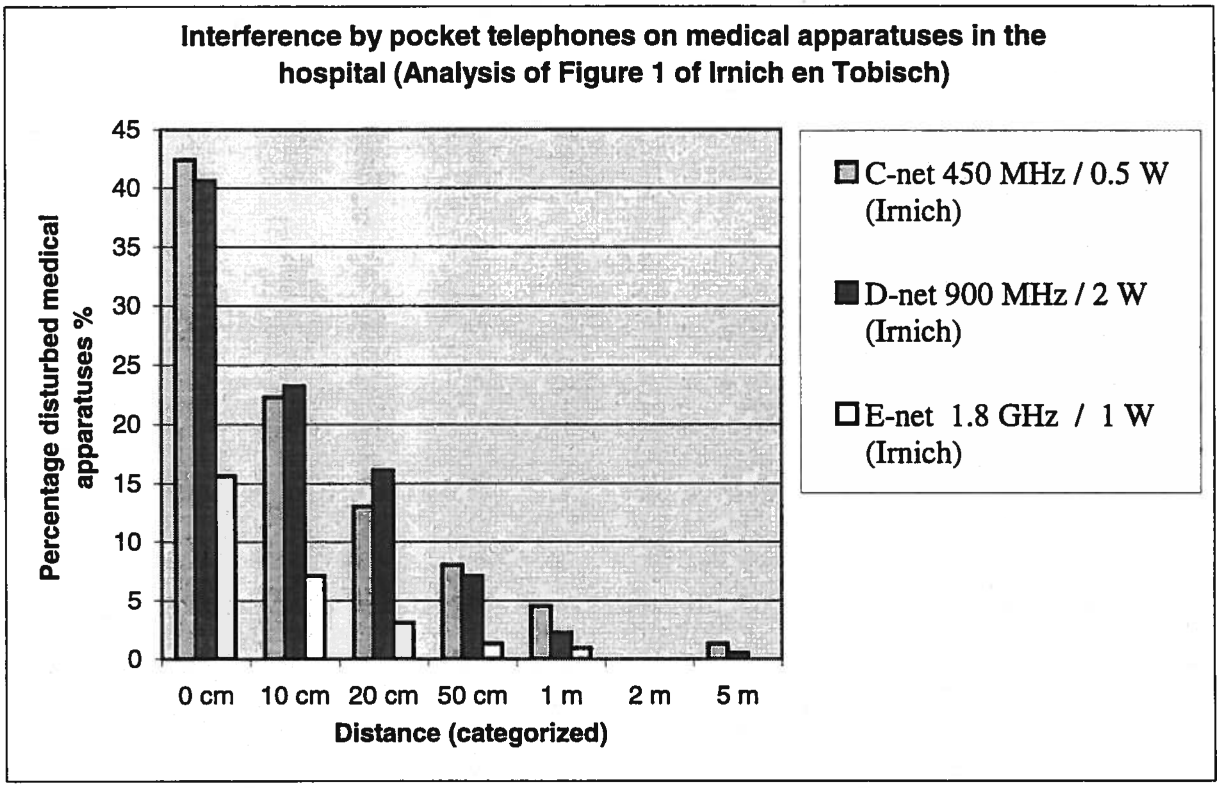
ECRI[72] notes that, on average, Irnich en Tobisch[73] found a 3-fold higher influence ('likelihood of interference') for 900 MHz than for 1800 MHz pocket phones, but do not elaborate this analysis. If one does, the results found provide more insight than they do at first sight.

This section elucidates the following two empirical rules of thumb that help explain interference outcomes published independently of one another.

These rules of thumb are as follows. In the frequency range of 400–1800 MHz the likelihood of interference:

- increases with the square root of transmitting power (for example, a 4-fold higher power results in a 2-fold higher likelihood of interference).
- decreases in an inversely proportional fashion with increasing frequency (for example when the frequency is doubled, the likelihood is halved).

These rules of thumb help explain the results found by Irnich and Tobisch as follows (presented below again). The proportion of disturbed apparatuses was similar for C-net and D-net. Relative to C-net, D-net operates at a two-fold higher frequency (thus, a halved likelihood of interference) and a four-fold higher power (thus, a doubled likelihood of interference). The combined result is a similar likelihood of interference (proportion of disturbed apparatuses) for C-net and D-net. Similarly, relative to D-net, E-net has a two-fold higher frequency (thus, a halved likelihood of interference) and a two-fold lower power (thus, a $2^{1/2}$ lower likelihood of interference). The combined result is a ca. 3-fold lower likelihood of interference. This relationship can be seen in the below histogram: roughly, for each distance category the rightmost bar is three-fold smaller than the other two bars.

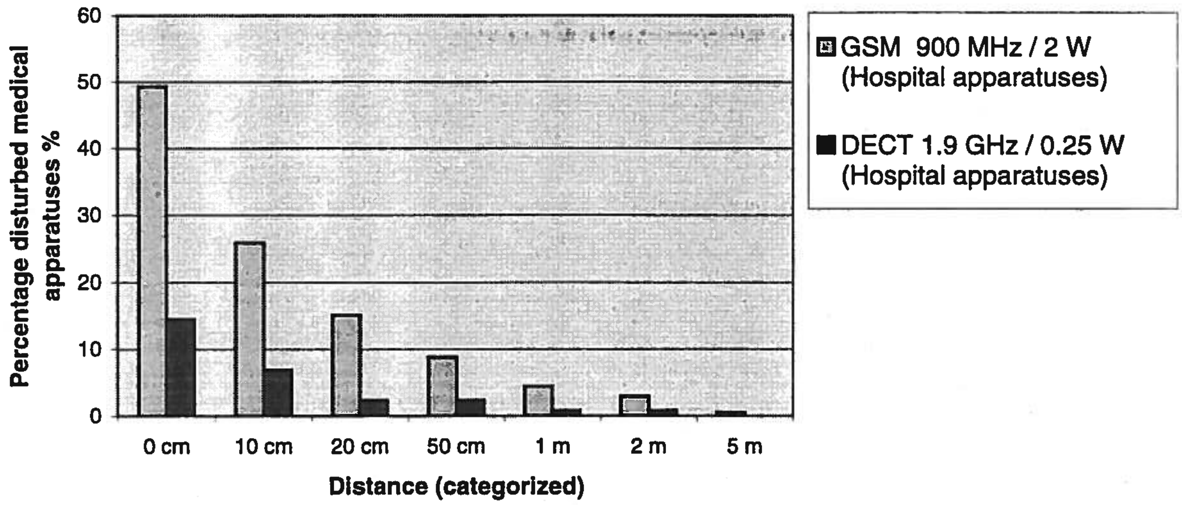


Interference by pocket telephones on medical apparatuses in the hospital (Analysis of Figure 1 of Irnich en Tobisch)

[72] ECRI publication 1999, reference [7].
[73] Tobisch en Irnich's book, reference [5].

The results previously found by TNO [74] [75], too, reasonably fit in with the two rules of thumb, as shown in the below histogram. DECT operates at 1.9 GHz and hence has a 2.1-fold lower likelihood of disturbance than GSM 900 MHz (1900/900). DECT has a power (0.25 W) 8-fold lower than that of GSM 900 MHz/2 W and hence 2.8-fold lower likelihood of interference ($8^{1/2}$). Thus, the combined likelihood of interference is ca. 6-fold lower likelihood of interference for DECT 1.9 GHz/0.25 W than for GSM 900 MHz/2 W. The histogram roughly shows a ratio of 4, which fairly approximates the hypothesized ratio of ca. 6.

Interference by pocket telephones on medical apparatuses in the hospital (Analysis of TNO results published earlier)



The results of a study by MDA (UK)[76] can also be explained quite well with these rules of thumb.

Intuitively, the first rule of thumb is easily explained from the notion that the field strength is proportional to $P^{1/2}$.

The second rule of thumb can be explained plausibly by assuming that the antenna efficiency with which the circuits of medical equipment unintentionally receive the interfering signal halves when the frequency is doubled. This relationship can be explained as follows: frequencies of 400–1800 MHz correspond with wavelengths of 75–15 cm. The unintended antenna action often involves resonance on ¼ of the wavelength, i.e. 19–4 cm for frequencies of 400–1800 MHz. Apparently, sensitive circuits with a length of 19 cm are more common that those 4 cm long. According to this reasoning, smaller medical apparatuses should be less susceptible than larger ones. On average, this is probably the case, but there is no scientific proof for this proposition.

Finally, it should be noted that these rules are rules of thumb indeed and that they apply to the 'average likelihood'. The interference behaviour of a specific apparatus may deviate appreciably from these rules of thumb.

[74] Reference [1].
[75] Reference [2].
[76] MDA publication (UK) of 1997, reference [8].

Appendix B Overview of mobile radiotelephony systems

This appendix describes systems that are currently used or will be used in the foreseeable future in the Netherlands and abroad. Comparison of systems in different countries often leads to confusion because different countries are using different systems and different national (sales) names which are used liberally in the international literature without stating explicitly national designations are used. For example, the DCS 1800 system is called 'PCN' (personal communication network) in the UK and 'E-Netz' in Germany, and GSM is usually called 'D-Netz' in Germany. In the UK, an analogue system operating at 900 MHz has been introduced ('TACS'), while the analogue system in Germany ('C-Netz') operates at 450 MHz. In the USA, 900 MHz 'handheld cell phones' transmit with a power of 0.6 W, while 900 MHz (GSM) pocket phones in Europe transmit with a power of 2 W. Different powers lead to differences in the likelihood of interference with medical equipment. Such differences are reason enough to order in this appendix all systems involved. Its should be noted in this context that new standards are set or provisional standards become in force practically every year

1. General characteristics

In mobile telephony, six main groups can be distinguished each of which constitutes a specific network:

1 Cellular mobile radio systems
2 Cordless telephone systems, CT
3 Private/professional mobile radio, PMR
4 Radio local area networks, RLANs
5 Flight telephones
6 Satellite systems

1.1. Cellular mobile radio systems

A cell is an area with a diameter of, for example, some kilometres, in which a telephone communicates with a base station at a frequency different from the frequencies for adjacent cells. More distant cells can use the same frequency (efficient use of the ether). When a cell border is passed, the system is switched automatically to a different frequency. Cellular systems use different frequencies for 'uplink' (from mobile phone to base station) and 'downlink' signals (form base station to mobile phone). Users of cellular systems are connected with the public telephone network.

First-generation cellular systems are analogue (e.g. NMT 450 introduced in 1981, TACS and ETACS in 1985, and NMT 900 in 1986). They operate at frequency bands around 150, 200, 450 and 900 MHz. In the first years of this century, analogue cellular systems will be replaced by digital cellular systems. The transition from analogue to digital will take place because the capacity (number of channels) of analogue systems has reached its limit. Digital systems have a greater capacity than analogue ones.

The first European digital system (GSM, 1991) consists in pocket phones with a peak transmitting power of 2 W, while the peak transmitting power for the first American digital system (NDAC/D-AMPS, 1991) is only 0.6 W. For the second American digital system (NADC / IS – 95) the peak transmitting power of the handheld telephones is even only 0.2 W. For that reason, there are fewer concerns about interference with medical equipment in the Americas than elsewhere. The European DCS 1800 system, which was established in 1993 and gradually implemented since 1998, works at a frequency of 1.8 GHz, while the peak transmitting power of these pocket phones is 1 W. (See below sections for more details on GSM ~~en~~ and DCS 1800.)

1.2. Third-generation mobile communication system

Digital systems are usually called 'second-generation' system as distinct from the 'first-generation' systems, the analogue cellular systems. The 'third-generation' system is now called IMT-2000 (International system for Mobile Telecommunication) for 3G (for 3rd generation). Talks about this system in the International Telecommunication Union (ITU) will probably result in a combination of two systems with internationally the strongest position world-wide, the time multiplex technology (Time Division Multiple Access, TMDA), the European standard technology currently applied in GSM, DCS 1800, CT 2, DECT and TETRA, and the code multiplex technology (Code Division Multiple Access, CDMA), which is predominantly applied in the USA in some variants. The result for the user could be a pocket phone capable of automatically switching from one technology to another and also fitting in with currently used second-generation systems. At the time of measurements in the current study, too little was known about third-generation systems to include them in practical tests.

1.3. Cordless telephony systems, CT

A cordless telephone (CT) is connected to a telephone line in place of a standard, fixed telephone. The 'mouthpiece' is a cordless device designed as sort of mobile phone and can communicate over a limited distance (within a building, for example) with the base telephone via the air. The user has access to the public telephone network. If required, multiple cordless phones can communicate with one and the same base telephone. A limited transmitting power suffices as the distance form the base apparatus is limited.

The first-generation CT systems (CT 0 en CT 1) are analogue systems for use at home. The second-generation, digital CT systems (CT 2, DECT, PHS, with a peak transmitting power ≤250 mW) have been designed as cellular systems with a transmission range limited, for example, to buildings or premises.

Cordless systems are less expensive than mobile systems because of their limited transmission range and because less facilities/functions have been built in than in mobile systems.

1.4. Private/professional mobile radio, PMR

PMR systems are systems for communication among vehicles in a fleet or among individuals provided with a 'hand unit'. Usually there is a base station through which all communication takes place. Communication is restricted to the phones included in the network; there is no connection with the public network. Examples are walkie-talkies and phones of taxis, ambulances, police, fire brigades and security services. Peak transmitted power may be appreciably higher than 2 W and may be even amount to some tens of watts for mobile phones built into vehicles and the like. In the TETRA system defined for Europe in 1997, also a hand-held phone with a peak transmitting power of 1 W is defined, but some hand-held units within the TETRA system may transmit at higher power. The TETRA system is a digital PMR system that, like GSM, DCS 1800, CT 2 and DECT, is based on a number of time slots (see below).

Some PMR systems transmit speech, some transmit data, and some transmit both. PMR systems that only transmit data are also called 'wide area networks' (WANs) as distinct from LANs (see below).

1.5. Radio local area networks, RLANs

Local area networks (LANs) are cable systems that connect computers with one another or with a central server. Computers are rendered mobile by means of a radio connection. For example, they can be placed on a lorry. A synonym of RLAN is 'wireless LAN' (WLAN). RLANs have hardly been standardized thus far. These systems have a great potential, among other reasons because the likelihood of interference is limited because of their relatively low transmitting power (see, for example, Dempsey[1], who has evaluated a 2.4 GHz WLAN with a transmitting power of 100 mW on interference and health effects.

1.6. Flight telephony

Phones of terrestrial analogue or digital cellular systems are banned in aeroplanes because of their potentially hazardous effect on (navigation) systems aboard. These cellular systems have not been designed anyhow for pocket phones switching from one cell to another with flying speed. Therefore, special flight telephone systems have been developed that are safe to aeroplane systems and connect with special ground stations providing access to the public telephone network.

1.7. Satellite systems

Satellite systems allow of communication in areas in the world with a very low population density or where ground stations cannot be built for whatever reason (sea, desert, some mountainous areas). Systems like INMARSAT and IRIDIUM have mobile/portable transmitters/receivers with a peak transmitting power of 7 W or more. In the GLOBALSTAR system a 'pocket phone' with a peak transmitting power of 1 W is being planned.

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[1] M.K. Dempsey: The Physiological Effects of 2.4 GHz Frequency Hopping Radios. WLI Forum, Wireless LAN Interchangeability Forum, Sunnyvale, CA, http://www.wlif.com. The publication is accessible on: http://www.wlif.com/pdfs/physio.pdf

2. Aspects covered by this study

2.1. Cellular mobile radio systems
The digital cellular systems **GSM** and **DCS 1800** were included in this study because an explosive growth in the use of pocket phones in Europe is anticipated. No analogue system was included because analogue cellular systems will be replaced by other systems in the next few years.

2.2. Cordless telephony systems, CT
Cordless telephony systems were included in the study because the use of large numbers of such systems at home is anticipated. An analogue **(CT 0)** and digital CT system **(DECT)** were included in order to verify whether these systems do not interfere indeed with medical equipment, as may be expected on the basis of the low peak transmitting power of CT phones.

2.3. Private/professional mobile radio, PMR
PMR systems were not included in the study because such systems are not going to be used in or around private houses in large numbers. Although it cannot be excluded that medical equipment at home is disturbed by some equipment within PMR systems transmitting outside the house due to the high transmitting power of some of these systems, it will not occur frequently enough to justify inclusion of such equipment in this study. Besides, it is an established fact that strong transmitters of the PMR type can interfere with electronics.

2.4. Radio local area networks, RLANs
RLANs were not involved in the study because no large numbers of these systems will be used and because no interference with medical equipment at home is to be expected.

2.5. Flight telephony
These systems were not included because no interference with medical equipment at home is to be expected.

2.6. Satellite systems
Satellite systems were not included because, for the time being, no large numbers of 'satellite pocket phones' were to be expected and because they still do not function well within houses (only close to a window and in 'sight' of the satellite).

3. Characteristics of signals transmitted by pocket phones

Prior to describing in more detail the systems included in this study, we will first explain three important concepts related to the characterization of signals (and hence fields) transmitted by pocket phones, viz. the concepts of 'time multiplex', 'automatic adjustment of the transmission level' and 'spectrum'.

3.1. Time multiplex, a special mechanism in some systems
In the GSM system, for example, a particular channel is shared by 8 phones which transmit by turns: when one phone transmit, the other seven remain silent. The turns are changes at so rapid succession that the users do not notice it. This process is named 'time multiplex', with multiple phones 'multiplexing' in time. Every phone has its own 'time slot' during which it transmits, e.g. with 2 W peak power. Subse-

quently, the phone is 'silent' for 7 time slots. Thus, the average transmitting power of phones with a peak power of 2 W is 0.25 W Ave (2:8). As the time multiplexing process proceeds through microprocessors it is a digital system. Time multiplex is applied in various systems including GSM, DCS 1800, CT 2, DECT and TETRA.

3.2. Automatic adjustment of the transmitting power of pocket phones

If the base station receives well the signal of the pocket phone, the power of the phone is automatically down-tuned in order to safe battery capacity and to reduce the risk of interference between pocket phones in different cells. This 'adaptive power control' is done by the system without the user noticing any effect on the speech connection.

3.3. Spectrum

Systems based on time multiplex (such as GSM, DCS 1800, CT 2, DECT and TETRA) operate with frames containing the time slots. The repeat frequency of the frames depends on frame length, which is determined on its turn by the number of time slots. For GSM and DCS 1800, the frame length is 4.615 ms, hence the frame repeat frequency is 217 Hz. A GSM or DCS 1800 frame contains 8 time slots of 0.577 ms each. The frame repeat frequency is 100 Hz for DECT and 500 Hz for CT 2. Thus, the spectrum of these systems also encompasses frequencies of 217, 100 and 500 Hz and, in addition, their harmonics (i.e. multiples of 217, 100 and 500 Hz).

Because, in some communication systems, there are periods in system control longer than those of the time slots and frames, the signal spectrum of GSM, DECT, DCS 1800 and TETRA also encompass low frequencies (e.g. 2 and 8 Hz and their multiples for GSM and DECT).
Because GSM, DECT, DCS 1800, CT 2 and TETRA are pulsed systems, magnetic fields are formed in the close vicinity of the telephones. Linde and Mild (in an EC report) and Andersen et al. (in an EC rapport) measured low-frequency magnetic flux densities up to 1.8 μT rms.

3.4. GSM

The Global System for Mobile communications, GSM (in French: Groupe Special Mobile) is a European standard designed to function worldwide via 'roaming agreements' among network operators. It is a cellular system. Initially, the base stations were built primarily along motorways – hence the designation 'mobile'. With ever more base stations, also in cities, the percentage of cover of GSM improves and its character shifts from 'mobile' towards 'hand-held/pocket'. The frequency bands are close to those of TACS/NMT systems in order to facilitate the gradual transition of these analogue systems to GSM.

The bands of the older systems, which will be replaced by GSM on the long run, lie 'in between' the GSM bands:

- CT 1: 914–915 MHz and 959–960 MHz,
- TACS/NMT: 890–905 MHz and 935–950 MHz,
- CT 2+: 944 and 948 MHz.

3.5. DCS 1800

The Digital personal Communication System, operating at 1800 MHz, is the successor and extension of the GSM system. Its technical configuration bears strong resemblance with the GSM system. Like GSM, it has 8 time slots and its frame frequency is 217 Hz.

3.6. DECT

The Digital Enhanced (European) Cordless Telecommunication system has been designed for cordless communication with PABX telephone exchanges, a specific type of switchboards, and for cordless communication in a wireless LAN. It is a cellular, digital system with a low transmitting power (a low range, ca. 200 m). It is used predominantly within offices. Its technical configuration bears strong resemblance with the GSM system. Like GSM, it has 8 time slots and a repeat frequency of 217 Hz.

4. Characteristics of systems

The characteristics of the most common systems are listed in the below table.

CELLULAR	ANALOGUE
TACS / NTACS / ETACS	Total Access Communication Systems (ETACS = Extended TACS, with 7% more channels than TACS) ANALOGUE/CELLULAR; frequency bands between 860 and 960 MHz In the UK, it is named Vodafone analogue network or Cellnett analogue network
	E.g. UK, Ireland, Austria, Italy, Spain, 1985 (will disappear in 2005). Highest peak transmitting power for pocket phones 0.6 W (ETACS also higher) Transmitting power of TACS pocket phones is not adjusted automatically, in contrast to ETACS Definition document: MPT 1324 (1987), TACS Spec. (1991)
NMT 450	Nordic Mobile Telephone, operating at ca. 450 MHz ANALOGUE/CELLULAIR; 453–458 MHz and 463–468 MHz In the Netherlands, NMT 450 was also named ATF2 = AutoTeleFoon 2
	E.g. western Europe, 1981 Highest peak transmitting power of pocket phone 1.5 W Transmitting power is not adjusted automatically The Dutch ATF2 network was closed in 1995. The German C-net is an NMT 450 system working with 'handies' of 0.5 W[2]. There were also C-net portable devices working on a big battery and operating at 2.5 W. In the literature, the latter devices are sometimes referred to as 'C-net 2.5 W'.
NMT 900	Nordic Mobile Telephone ANALOGUE/CELLULAR; 890–915 MHz and 935–960 MHz In the Netherlands, NMT 900 was also called ATF3 = AutoTeleFoon 3
	In the Netherlands, Scandinavia, Switzerland, etc., 1986. The Dutch ATF3 network was closed in 1999. Highest peak transmitting power for pocket phone: 1 W. Transmitting power is adjusted automatically.

[2] Tobisch and Irnich's book, reference [5]

AMPS	**Advanced Mobile Phone Service** ANALOGUE/CELLULAR; 824–849 MHz and 869–894 MHz
	North America, for example. Highest peak transmitting power for pocket phones: 0.8 W Transmitting power of pocket phones is not adjusted automatically.
CELLULAR	DIGITAL
GSM	**Global System for Mobile Communications** DIGITAL/CELLULAR; 880–888 MHz, 890–915 MHz, 925–933 MHz, 935–960 MHz
	Europe, Asia, Pacific, etc., 1991 Frame frequency 217 Hz Highest peak transmitting power for pocket phone: 2 W peak ± 2 dB (–37%/+58%) Average transmitting power for pocket phone: 0.25 W Ave ± 2 dB (–37%/+58%) Vehicle set: up to 20 W Transmitting power of pocket phones is adjusted automatically. NOTES: • The '910 MHz' version of the GSM standard is currently in use in Europe; the standard defines various other bands. • In the UK, the commercial names of GSM are Vodafone digital network and Cellnett digital network. • The German D-net is a GSM system. Definition document: ETS 399 577 (ETSI GSM 05.05)
DCS 1800	**Digital personal Communication System, operating at ca. 1800 MHz** DIGITAL/CELLULAR; 1710–1785 MHz, 1805–1880 MHz
	Europe, 1993 (gradually implemented in the Netherlands from 1998) Frame frequency 217 Hz Highest peak transmitting power for pocket phone: 1 W peak ± 2 dB (–37%/+58%) Average transmitting power for pocket phone: 0.125 W Ave ± 2 dB (–37%/+58%) Vehicle set: up to 20 W Transmitting power of pocket phones is adjusted automatically. NOTES: • Is also named 'GSM 1800' because its modulation is comparable to that of GSM. • In the UK, it is called PCN (Personal Communication Network), with the commercial names Orange DCS 1800 and One 2 One DCS 1800. • The German E-net is a DCS 1800 system. Definition document: ETS 399 577 (ETSI GSM 05.05)

NADC/D-AMPS	**North American Digital Cellular/Digital Advanced Mobile Phone Service** DIGITAL/CELLULAR; 824–849 MHz and 869–894 MHz
	North America, for example, 1991 Frame frequency 50 Hz Highest peak transmitting power for pocket phone: 0.6 W Transmitting power of pocket phones is adjusted automatically. Definition document: IS 54, IS 55, IS 56, IS 136
NADC/IS-95	**North American Digital Cellular** DIGITAL/CELLULAR; 824–849 MHz and 869–894 MHz
	North America, for example, 1995 Frame frequency 50 Hz Highest peak transmitting power for pocket phone: 0.2 W Transmitting power of pocket phones is adjusted automatically Definition document: IS 95
PCS	**Personal Communication Systems (Services?)** DIGITAL/CELLULAR; 1850–1910/1930–1990 MHz
	E.g. USA, 1996 Open system which includes several other systems (e.g. a type of DCS 1800 operating at 1900 MHz, a type of IS-95, a type of PHS and a type of DECT) NOTE • See also 'PCN' under DCS 1800. PCS and PCN are highly similar.
IMT-2000	**International Mobile Telecommunications 2000.** Worldwide standard for how third-generation mobile telecommunication systems will develop[3]. See UMTS for details.
UMTS	Universal Mobile Telecommunications System. The European CEPT standard for IMT-2000. Will operate in Europe in the bandwidths 1900–1980 MHz, 2010–2025 MHz and 2110-2170 MHz for terrestrial systems. In Europe, the bands 1980–2010 MHz and 2170-2200 MHz are reserved for mobile satellite services, UMTS included. Definition document: CEPT/ERC/DEC(99)25 dd. 29 November 1999. This document does not specify transmitting power[4]. UMTS will start in 2002. On the longer run (possibly in 2008) the GSM network will merge into UMTS.
CORDLESS	**ANALOGUE**
CT 0	ANALOGUE; 31 and 40 MHz (frequencies in the Netherlands and Spain) E.g. in Europe, USA, Australia, Asia Highest peak transmitting power for pocket phone: 10 mW. Transmitting power of pocket phones is not adjusted automatically.
CT 1 CT 1+	ANALOGUE; 914/959 MHz ANALOGUE; 885/932 MHz
	Highest peak transmitting power for pocket phone: 10 mW Transmitting power of pocket phones is not adjusted automatically.

[3] http://www.itu.int/imt/vision.html
[4] European Radiocommunications Committee (ERC), http://www.ero.dk

CORDLESS	DIGITAL
CT 2 CT 2+	DIGITAL/CELLULAR; 864.1–868.1 MHz DIGITAL/CELLULAIR; 944–948 MHz
	Defined worldwide in 1989; popular in Australia and the Far East. Frame frequency: 500 Hz (2:1 time multiplex) Highest peak transmitting power for pocket phone 10 mW peak; Ave 5 mW. Transmitting power of pocket phones is adjusted automatically. Definition document: ETS 300 131
DECT	**D**igital **E**nhanced (European) **C**ordless **T**elecommunications DIGITAL/CELLULAR; 1880–1900 MHz
	Europe, 1994 Frame frequency 100 Hz Highest peak transmitting power for pocket phone: 0.250 W peak Average transmitting power for pocket phone: 0.01 W Ave Transmitting power of pocket phones is not adjusted automatically. NOTES • Channels are shielded against tapping by means of a Cyclic Redundancy Code (CRC). • Definition document: ETS 300 175-2 (1993), I-ETS 300 176 TBR6 • Blue tooth is a new technology for WLAN communication between apparatuses over a distance of 10–100 m. This technology will possibly enter the market in 2001. It bears resemblance to DECT but operates at 2.45 GHz. It is a worldwide free band, which enhances the likelihood of worldwide standardization. The bandwidth is 80 MHz. The transmitting power will probably be ca. 10–100 mW but might be higher.
PHS	**P**ersonal **H**andy phone **S**ystem DIGITAL/CELLULAR; 1895–1918 MHz
	Japan, 1994 Frame frequency 200 Hz Highest peak transmitting power for pocket phone: 80 mW Transmitting power of pocket phones is not adjusted automatically. Definition document: RCR Spec. Std 2B (TBA)
PRIVATE/PROFESSIONAL MOBILE RADIO (PMR)	
TETRA	**T**rans **E**uropean **T**runked **Ra**dio system; professional applications DIGITAL; 380–385 MHz and 390–395 MHz
	Defined for Europe in 1997 Frame frequency 17.65 Hz Highest peak transmitting power for pocket phone: 1 W and higher Transmitting power of pocket phones is adjusted automatically. Definition document: ERC/DEC/(99)04 dated 10 March 1999 (this document does not specify transmitting power).

RADIO LOCAL AREA NETWORKS (RLANs)	
HIPERLAN 1)	**High-Performance European Radio Local Area Network** DIGITAL; bands around 5.2 GHz (in 1996)
	Defined world-wide in 1996 (?) Highest peak transmitting power of pocket phone: 1 W. Definition document: prETS 300 652
HIPERLAN 2)	**High-Performance European Radio Local Area Network** DIGITAL; 17.1–17.3 GHz
	Defined world-wide in 1996 (?) Highest peak transmitting power for pocket phone: 0.1 W. Definition document: prETS 300 652
WLAN	See under DECT
FLIGHT TELEPHONY	
INMARSAT AERO	**International MARitime SATellite, AERO version** DIGITAL/CELLULAR; frequency bands around 1.6 GHz
	Defined world-wide Highest peak transmitting power for mobile unit: 25.5 dB W Transmitting power of mobile units is adjusted automatically.
SATELLITE SYSTEMS	
INMARSAT	**International MARitime SATellite** Various CELLULAR systems, both ANALOGUE and DIGITAL ones; frequency bands around 1.6 GHz
	Most systems have a worldwide coverage except for the poles. Highest peak transmitting power for mobile unit: 33–36 dB W Transmitting power of mobile units is adjusted automatically in some IMMARSAT systems but not by others.
IRIDIUM draft specification	Frequency bands near 1.6 GHz Highest peak transmitting power for mobile units: 7 W Transmitting power of mobile units is adjusted automatically. The 70 satellites of the IRIDIUM network will be destroyed in default of buyers (source NRC Handelsblad newspaper of 1 April 2000)
GLOBALSTAR draft specification	Frequency bands near 1.6 and 2.5 GHz Highest peak transmitting power for mobile units: 1 W and higher. Transmitting power of mobile units is adjusted automatically.

PR 27	Radio amateurs 26.960–27.410 MHz 4 W

5. Extent of penetration

Early in 2000, ca. 40% of all Europeans was in the possession of a mobile telephone. The Fins ranked first, with 70%. In 1999, a total of 284 million mobile phones were sold across the world.[5] In the same year, also the 200 millionth GSM telephone was sold.[6] According to the GSM Association[7], an industrial organization, 4 new GSM customers joined the ranks every second in the beginning of 2000. This means an annual increase in number of GSM customers of 63 million ('angle of inclination' of early 2000).

According to Dutch TV newscast, there were some 6 million Dutch mobile callers on 6 April 2000. According to NRC Handelsblad newspaper, there were slightly over 15 million mobile callers on that date in the UK.

The expected worldwide expansion of mobile telephony is reflected in the below table.[8] As can be read from the table, markets in North America and Europe will be the first to reach the saturation point. Even in 2015, the markets in Asia, Africa and South America will still be far away from that point, even if population growth is not allowed for. These figures were also cited in the magazine "Elektronica" of November 1999.

Customers in millions at year end	1995	2000	2005	2010	2015
EU 15	22	113	200	260	300
North America	36	127	190	220	230
Asia Pacific	22	149	400	850	1400
Rest of world	7	37	150	400	800
Total	87	426	940	1730	2730

It is anticipated that mobile telephones will outnumber fixed phones by 2010.

6. Concepts

Some frequently used concepts in mobile telephony are listed below.

Analogue system	A system in which speech signals directly modulate a carrier wave, just like in frequency-modulated (FM) and amplitude-modulated (AM) radio signals. Consequently, the communication signal is analogous to the speech signal.
X Digital system/digital network	The speech signal is converted to ones and zeros (on and off), which modulate the carrier wave.

klein lettertype ?

[5] NRC Handelsblad newspaper, 14 March 2000.
[6] Elektronica monthly, November 1999
[7] http://www.gsmworld.com/technology/tech_faq.html
[8] http://www.siriuscomm.com/umts_regdirect.htm :

Cellular system/cells	A cell is an area within which a telephone communicates with a base station at a frequency that cannot be received in adjacent cells. In contrast, telephones in cells further away can transmit at the same frequency (efficient use of the ether). When passing a cell boundary, the system switches automatically to a different frequency. Both the older analogue (NMT) systems and the newer systems GSM, DECT, CT 2, DCS 1800 and TETRA are cellular systems.
Base station/fixed station	A fixed antenna usually aimed at (part of) a cell via which mobile or pocket phones communicate. The base station gives the phone access to the telephone network in which exchanges regulate the traffic.
Percentage of cover	A figure reflecting the percentage of a given area in which a mobile or pocket phone can be reached
Mobile phone	A phone intended for use in a vehicle. It can be used outside the vehicle after being charged in the vehicle.
Pocket phone/Handy	Intended to be carried in a jacket pocket. It must be charged in a charger and/or by changing the battery.
Portable device	Device in a bag or case that also contains a powerful battery to prolong the capacity. Often a charger is built in to charge the battery from the 230 V electricity grid or form the car battery. Application: communication in the absence of electricity.
Amateur band/Citizen's Band (CB) '27 Mc rig'	In a frequency range around 27 MHz, users may transmit without a licence but under specific conditions (e.g. the transmitting power may not exceed 4 W, and only the FM modulation may be used). In the USA, this frequency is called the 'amateur band' or the 'Citizen's Band' (CB). In the Netherlands, it is often referred to as '27 Mc', where 'c' stands for cycle, as a synonym of Hz (hertz). This band is frequently used illegally, often with too high a transmitting power. Worldwide, radio amateurs have been allocated frequency bands other than 27 MHz, in which transmission is subject to fairly stringent restrictions. Amateurs who fail to meet these conditions are banned from radio ham societies and may lose their broadcasting licence.
Pager	A device that can receive messages which are displayed on a small screen and/or can be listened in. The messages are usually entered via the telephone. Some pagers are also able to send a return message.

Power (in W = watt)	Energy (in joule, J) per second.
Average (Ave) power	For example, a system transmitting for 1 second at a power of 2 W followed by 7 seconds of 'silence', 1 second of transmission, and so on, transmits with an average power of 2:8 = 0.25 W Ave. In that case, the average transmitting power is 0.25 W Ave.
Peak transmitting power	In the above example, the system transmits at its peak power in each transmission period of 1 second. Consequently, its peak transmitting power is 2 W.
LAN and RLAN	Local Area Network (see description in the section about RLANs (1.5 in this Appendix).

7. Units and quantities

ms	= 0.001 second	
mV	= 0.001 V	
W	= watt = joules per second	
mW	= 0.001 W	
Hz	= cycles per second	
kHz	= 1000 Hz	
MHz	= 1000,000 Hz	1 MHz = 1000 kHz
GHz	= 1000,000,000 Hz	1 GHz = 1000 MHz
dB	20 log(A/B) ['voltage dB'] = = 10 log (C/D) ['power dB']	A/B is a voltage ratio; C/D is the corresponding power ratio.
dBm	10 log(P/0.001)with P in W	0.001 W = 1 mW; hence the 'm' in dBm.
dBW	10 log(P) with P in W Often written dB (with the W omitted) if it is clear from the context that the unit referred to is dBW.	dBW = dBm – 30

Appendix C Peak power of various types of pocket phones and the like

Type	A/D	Peak power[21]	Average power	Frequency
GSM European, e.g. D-net (D)	D	2 W (handy) 8 W (mobile)	0.25 W (handy) 1 W (mobile)	900 MHz „
Cell(ular) phone e.g. D-AMPS (USA)	D	0.6 W (hand-held) 3 W (mobile)	0.2 W (hand-held) 1 W (mobile)	900 MHz
Cell(ular) phone e.g. AMPS (USA)	A	0.8 W (hand-held)	0.8 W (hand-held)	band around 860 MHz
NMT analogue e.g. C-net (D)	A	0.5 W (handy) 2.5 W (portable) 15 W (mobile)	0.5 W (handy) 2.5 W (portable) 15 W (mobile)	450 MHz „ „
NMT 900 e.g. ATF3 (NL)	A	1 W	1 W	band around 900 MHz
TACS, NTACS, ETACS (until 2005) e.g. Vodafone (UK) and Cellnett (UK)	A	0.6 W	0.6 W	band around 900 MHz
DCS 1800, GSM 1800 e.g. E-net (D) and PCN (UK)	D	1 W	0.125 W	1800 MHz
DECT	D	0.25 W	0.01 W	1.9 GHz
FHSS LAN	D	0.1 W	0.1 W	2.4 GHz
CT 0	A	10 mW	10 mW	31 and 40 MHz
CT 1	A	10 mW	10 mW	900 MHz band

[21] 'Handy' is the term commonly used in Germany for pocket phones, 'portable' for portable equipment which used to be carried as 'shoulder bag', and 'mobile' for equipment built in in a vehicle.

CT 2	D	10 mW	5 mW	900 MHz band
Walkie-talkie	A	2.5 W	2.5 W	435 MHz
CB (citizen band in USA and UK)	A	4 W	4 W	27–28 MHz
UHF walkie-talkie (USA: business band)	A	5 W	5 W	450/465 MHz
Mobile radio (USA)	A	20 W	20 W	465 MHz
Amateur radio (USA)	A	5 W	5 W	465 MHz

Appendix D Apnoea monitors listed in reference [5]

Distances in cm to apnoea monitor

Producer	Device type	Serial number	C 0.5 W	C 2.5 W	D 2 W	D 8 W	E 1 W	DECT	Notes
GeTeMed	VG 100 IMP	01 95442	5	150	10	200			Respiration and cardiac rhythm are detected falsely. The equipment resets and restarts automatically.
Graseby	MR10S	820		10	5	50	1		The equipment resets and restarts automatically or must be switched on by hand. Heart frequency is falsely detected
Osypka	Baby Guard BS 1000	8901493	150	400	70	200	7		Movement of child is falsely detected.
Siss	Babycontrol AÜW 1	BC 7569	800	1400	40	400	3		Respiration and cardiac rhythm are falsely detected.

Remark (not from [5]):

C = NMT 450 MHz (analogue)

D = GSM 900 MHz

E = DCS 1800

Appendix E References

[1] Influence of 2 W GSM pocket phones on 205 medical apparatuses: field measurements. TNO research report TG/95.044. 1 August 1995 (Dutch Language only).

[2] Influence of DECT pocket phones on 131 medical apparatuses: field measurements. TNO research report TG/95.045. 1 August 1995 (Dutch Language only).

[3] Influence of CT 2 pocket phones on 106 medical apparatuses: field measurements. TNO- research report TG/95.046. 1 August 1995 (Dutch Language only).

[4] Recommendations regarding the use of pocket telephones within health care institutions, VIFKA, 1 September 1995 (VIFKA is now called Netherlands ICT Association). This report has been distributed worldwide and contains abstracts of references [1], [2] and [3].

[5] Tobisch, Rolf: Mobilfunk im Krankenhaus – Einfluβ von Mobiltelefonen auf lebensrettende und lebenserhaltende Medizintechnik [Mobile phones in hospitals: the influence of mobile phones on life saving and life sustaining medical equipment]. Rolf Tobisch, Werner Irnich. Situation January 1999; Schiele & Schön, Berlin. ISBN 3-7949-0640-3.

[6] Irnich, W. and R. Tobisch: Mobile phones in hospitals. Biomedical Instrumentation & Technology, January/February 1999, pp. 28-34. This paper is a summary of the book, Reference [5].

[7] Paper in ECRI's journal Health Devices of October 1999 entitled "Cell Phones and Walkie-Talkies, Is it Time to Relax Your Restrictive Policies", pp. 409–413.

[8] Medical Device Agency (UK): Electromagnetic Compatibility of Medical Devices with Mobile Communications. MDA Devices Bulletin DB 9702 dated March 1997. MDA Room 1207, Hannibal House, Elephant & Castle, London SE1 6TQ.

[9] Standard IEC 60601-1-2 entitled "Medical electrical equipment – Part 1: General requirements for safety. 2 Collateral standard: Electromagnetic compatibility - Requirements and tests". First edition, 1993-04.
See [10] as well.

[10] Draft second edition of the IEC 60601-1-2 standard entitled "Medical electrical equipment – Part 1: General requirements for safety. 2. Collateral standard: Electromagnetic compatibility - Requirements and tests".
Document Number: 62A/308/CDV, dated 2000-02-11.

Errata (integrated in this version)

TNO research report PG/TG/00.050 of 28 April 2000, “Effects on medical equipment at home of pocket phones and the like – field measurements”.

- The ISBN of this report is: 90-5412-064-9.

- Page 2 and page 7: For GSM/8 W, add the following footnote:
  GSM 8 W is not being used in the Netherlands any longer.

- Page 15: The vertical axis of the histogram starts with 0, not with 01.

- Page 15 and page 34: First of the two points: ‘the transmitting power squared’ should read ‘the square root of the transmitting power’. (The example illustrates this relationship.)

- Page 17: The note in smaller font says that ‘4 of the 224 apparatuses include 4…’. This should read ‘of the 224 apparatuses, 4 (2%)…’.