GSM base stations

The Minister of Housing, Spatial Planning and the Environment

Subject : presentation advisory report GSM base stations
Your reference : DGM/SVS/99207094
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Dear Sir,

In the past year and a half the use of mobile telephones has increased very rapidly and is still on the rise. As a result of this an increasing number of people is being exposed to the electromagnetic fields used for the data transfer between mobile telephones and base stations. This raises the question whether such exposure may result in negative health consequences. In September 1999 you and your colleague of Health, Welfare and Sport, also on behalf of the State Secretary of Transport, Public Works and Water Management, requested the Health Council to advise on this matter. A further official elaboration of this request indicated that in the short term especially advice was needed on GSM base stations, on behalf of the National Antennapolicy that is being formulated.

On 9 March 2000 I have established the Electromagnetic Fields Committee that will report on the scientific developments with respect to exposure to such fields on a regular basis, initially for a period of four years. The first assignment of this committee was to formulate an advisory report on GSM base stations. Having consulted the Standing Committee on Radiation Hygiene I herewith present you with this report.

The committee will now proceed to prepare a more general report on mobile telephony, in which also exposure to mobile telephones will be extensively dealth with. The committee will also anticipate in this report on new developments, such as the ‘third generation’ of mobile telephony, UMTS.

Yours sincerely,

(signed)
Dr JA Knottnerus

GSM base stations

to

the Minister of Housing, Spatial Planning and the Environment

the Minister of Health, Welfare and Sport

the State Secretary of Social Affairs and Employment

the State Secretary of Transport, Public Works and Water Management

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Contents

Executive summary

Mobile telecommunication has undergone an extremely fast development in recent years. Its rapid spread within society has, apart from the many practical advantages associated with its use, also led to questions about the negative health consequences that may arise as a result of exposure to the electromagnetic fields used in wireless communication. Such questions are of particular concern for people who are confronted with the placing of a base station near where they live.

In response to the questions of the ministers concerned, the Health Council's Electromagnetic Fields Committee discusses, in this advisory report, the construction of a base station and the electromagnetic fields in its vicinity. The field strengths are compared to the exposure limits proposed by the Committee, which are based on a survey of the scientific literature.

The Committee supports the exposure limits based on thermal effects as proposed in the advisory report entitled *Radiofrequency electromagnetic fields (300 Hz to 300 GHz)* published in 1997. Non-thermal effects do not provide a scientific basis for determining exposure limits. However, the ministers asked if there is a case for application of the precautionary principle to set the exposure limits at a level lower than the values proposed on the basis of thermal effects. The Committee has adopted a pragmatic approach to this question by investigating whether there is a reasonable suspicion that there are health risks associated with non-thermal effects. To its view this is not the case for the three categories of non-thermal effects considered in this report, namely biological effects, carcinogenesis and non-specific complaints. Thus the answer to the ministers' question is negative.

The chance of health problems occurring among people living and working below base stations as a result of exposure to electromagnetic fields originating from the antennas is, in the Committee's opinion, negligible. The field strengths are always considerably less than the exposure limits.

On the rooftop the field strength is generally higher than in the spaces underneath the roof. As the antenna's main beam is nearly always directed horizontally and the antennas are usually mounted a few metres above the roof surface, people on the rooftop will not be exposed to field strengths which exceed the exposure limits set for the general public.

As a rule of thumb it can be said that in an open space, the minimum distance to the antennas should be three metres in the beam and 0.5 m outside it. For most antennas this yields an extra safety margin but it is simpler and more practical to adopt the same distance for all antennas than to allow the distance to vary in accordance with the antenna's power.

At sites where people can get closer to the antenna than the distances stated above, precautions should be taken to prevent them from doing so.

In the case of exposure of workers, being defined as people who are familiar with the risks and with the precautionary measures to reduce them, higher exposure limits apply. For a distance of more than 10 cm above, below or behind an antenna no specific precautions are required. If the distance is smaller or a person needs to be within the main beam, special safety measures need to be taken.

The Committee believes that people who live or work in an area where a base station is to be constructed should be involved in developments from the start, i.e. the planning phase. This can prevent a lot of problems, as many health problems will be the result of a fear of the unknown, especially if 'radiation' is involved. Where complaints arise, these should always be treated seriously. In situations where information has not been provided, supplying it can remove many problems. In cases of persistent complaints, it should be investigated whether or not low-frequency noise or vibrations are involved.

At current field strengths in residences in the vicinity of base stations, the chances of medical, electrical or other electronic equipment suffering from interference can be virtually ruled out if such equipment meets the European immunity guidelines. As medical implants such as insulin pumps, pacemakers and other stimulators must meet stricter requirements than other medical equipment, the probability of these suffering interference, and the probability of associated health problems, is even lower. Should equipment nonetheless be affected (and that will almost certainly be the case with non-medical equipment only), then this must of course be dealt with as quickly as possible. The Interference Complaints Regulation provides sufficient guidance for such cases.

In the Netherlands, there is at present no legal provision for regulating the location of antennas (and thereby base stations) on the basis of health considerations. The Committee recommends a review of the relevant legislation, for example amendments to the Telecommunications Act or the Environmental Management Act.

The Committee proposes that the technical data, a field strength calculation and, if available, any measurements be centrally registered for each base station. The German approach could serve as an example. In Germany, the registration of each antenna with the authorities, accompanied by a location certificate detailing the above-mentioned data, is a legal requirement. Such a registration might assist in inspections and enforcement of the relevant legislation and in providing information to, for example, nearby residents.

Clarity is urgently needed with regard to the division of responsibilities for monitoring the building of new base stations and of the strength of the fields emitted, and with regard to ensuring that the relevant legislation is enforced. Further statements regarding this matter fall outside the Committee's brief. However, the Committee would like to point out that problems are more readily solved and can often even be prevented if the general public is aware as to whom they can direct their questions.

Chapter 1

Introduction

1.1 Background

In recent years, mobile telecommunications have experienced rapid growth. Public mobile telephone use in the Netherlands started in 1980 with ATF-1, the first car phone network. National coverage was provided by 29 base stations that could serve a total of 2000 car phones. Since then the pace of technological developments has been rapid, and with the arrival of the DCS 1800 system, in part due to concerted marketing efforts, mobile telephones are now accessible to everyone. An overview of these developments is presented in Table 1.

Table 1 The development of mobile telephony in the Netherlands.

year of introduction	network	number of base stations	number of users
1980	ATF-1	29	2000
1985	ATF-2	126	30 000
1989	ATF-3	363	> 250 000
1994	GSM 900	> 1000	> 6 000 000
1998	DCS 1800	> 6000	> 1 000 000

The ATF networks are no longer in use. Within a few years, newer systems and networks are to be introduced alongside the GSM 900 and DCS 1800 systems. An example is UMTS (Universal Mobile Telephone System), with which it will be possible to rapidly transfer large quantities of data. This will make possible mobile use of the Internet and mobile transmission of video images. For the realization of the UMTS networks, about 12 000 base stations will be needed.

In the Committee's view, the current possibilities for the use of mobile telecommunications involve both positive and negative aspects. An important positive aspect is that the increasing need for communication is being satisfied. People wish to contact each other in a simple and relatively cheap manner. Furthermore, possessing a mobile phone can reduce one's sense of being unsafe, something increasingly common in contemporary society. Contact with emergency services in the event of accidents can also be made more quickly.

Negative examples include, e.g., an increased level of disruption in public areas due to the diverse ringing tones that mobile phones emit, and people carrying on mobile phone conversations at an elevated volume. Mobile phone calls made whilst driving, even where a hands-free set is used, can compromise road safety (IEG00).

Whatever the reasons might be, it remains a fact that a large and ever growing group of people wish to use mobile telephony. This requires a network of transmitting and receiving stations (base stations) to be permanently established so as to ensure that one can phone with a disruption-free and qualitatively good link to the regular (cable) telephone network, regardless of one's location within the Netherlands. The number of such base stations has greatly increased, especially in the last two years. There are various reasons for this. Firstly, there is the demand for capacity. Each base station can currently handle only a limited number of calls. An increase in demand will necessitate the establishment of more base stations. The second aspect is the demand for quality. To obtain a good-quality link, regardless of one's location, including indoors, requires a fairly dense network of base stations. Thirdly, the government has decided to allow competition within the mobile phone market. Accordingly, there are now five operators working within the Netherlands. Each of these has its own system, which means that five separate networks are needed. The Telecommunications Act (Stb89) does require, however, that as much use as possible be made of the same base station locations.

Due to the increase in the number of base stations needed and the fact that the associated antennas must be placed at elevated locations, there is, especially in urban areas, a continuous search for tall buildings that provide such suitable locations. There is a shortage of available and suitably located commercial buildings that meet the technical requirements for the setting up of a network, and for a variety of reasons the placing of free-standing masts is not normally possible. For this reason, since the end of 1998 owners of high-rise residential buildings have been approached increasingly often for permission to place base stations upon their buildings. Due, in part, to the generous financial compensation offered for this, cooperation was readily available.

Residents of such buildings were subsequently confronted with uninvited activities on the roof, sometimes even during the night, connected with the mounting of an antenna installation. When it then came to their attention that such an antenna emitted ‘radiation’ – a term often associated with health threats – their anxiety was hardly surprising, considering that they had not in any way been involved in the planning and installation of the antenna, and were also not informed about relevant health issues. Assumptions about the frequent occurrence of health problems in the vicinity of such antennas then become widespread. In the second quarter of 1999 such reports spread rapidly in the Netherlands, and due to public disquiet, the locating of new base stations became increasingly difficult. Since then, both the government and the operators have done much to meet the need for advice and information. Many municipalities in the Netherlands have developed their own antenna policy or are currently preparing one. One of the most important questions associated with this is whether being resident in the immediate vicinity of a base station can constitute an increased health risk. In 1997, the Health Council of the Netherlands published a report entitled *Radiofrequency electromagnetic fields (300 Hz - 300 GHz)* (HCN97), in which recommendations regarding exposure limits were made, based on scientific data. This report is playing an important role in the discussion regarding health effects. However, it contains no specific recommendations with regard to base stations for mobile telephony. At the request of the Minister of Transport, Spatial Planning and the Environment, the Minister of Health, Welfare and Sport and the State Secretary of Transport, Public Works and Water Management, a Health Council Committee has compiled the present report.

1.2 The request for advice

In September 1999, the Health Council of the Netherlands received a request from the aforementioned ministers for an overview of relevant literature published since the report of 1997 and for conclusions and recommendations on the basis of this overview with respect to mobile telephony. The request for advice is given in Annex A. A further official explanation made it clear that the advice with respect to health aspects arising from living in the vicinity of a base station has high priority within the scope of the National Antenna Policy currently being developed by the Ministry of Transport, Public Works and Water Management. The request for advice also asks if there is a case, based on the so-called precautionary principle, for setting exposure limits at a level lower than the values proposed on the basis of findings on the scientifically established thermal effects. In other words, it poses the question whether the setting of standards should take into account possible health effects that are not scientifically demonstrated. Such measures have already been taken in Switzerland and Italy (Gaz98, Sch99). Whether or not the precautionary principle should be applied, however, is first and foremost a political decision. The Council can only submit material upon which such decisions can be based.

1.3 The Committee

The Health Council of the Netherlands has a long tradition with respect to the publication of reports concerning the health effects resulting from exposure to electromagnetic fields. In recent years the level of public interest in this subject has increased considerably, especially as a result of the strong growth in mobile telephony. Accordingly, the Council is continuously confronted with questions on this subject. So as to be able to answer these questions adequately, the President of the Health Council has decided, initially for a period of four years, to set up an Electromagnetic Fields Committee. The task of this Committee is to produce annual reports on the scientific developments within its area of remit and to respond to requests for advice. From time to time, as the need arises, the Committee must be able to give its opinion regarding the most important of these scientific developments.

The Committee, whose composition is given in Annex B, was inaugurated on 9 March 2000. Its first task was to answer the request for advice detailed in section 1.2, in which a report about the health aspects associated with living in the vicinity of a GSM base station has the highest priority.

1.4 Report structure

This report is solely concerned with base stations for the GSM 900 and DCS 1800 systems. A forthcoming report will consider mobile phones and other wireless communication systems.

Chapter 2 contains a description of GSM 900 and DCS 1800 base stations. In chapter 3 the Committee provides an overview of the relevant scientific literature up until the end of April 2000. This overview is predominantly based upon recent review articles. In Chapter 4 the Committee amplifies the precautionary principle. Chapter 5 contains the recommendations for exposure limits, which in Chapter 6 are compared to the actual electromagnetic field strengths present at base stations. Chapter 7 briefly examines low-frequency sounds and vibrations as possible alternative causes of health problems. The Committee's conclusions and recommendations, which include ones regarding several specific situations, are presented in chapter 8.

In addition to the request for advice and the composition of the Committee, the annexes contain an example of field strength measurements at a base station and an explanation of the methodology for summating field strengths of different frequencies.

Chapter 2

Description of a base station

2.1 Purpose

The purpose of a GSM 900 or DCS 1800 base station is to transfer signals between mobile telephones and a network for mobile or normal telephony by means of radiofrequency electromagnetic fields.

2.2 Construction

The Committee does not provide an extensive technical description of a base station in this section but rather a summary of its constituent parts and their function.

The following parts are always present:

- Antenna boxes consisting of a generally right-angled plastic casing between ca. 1 and 2.5 m in height, in which a number of dipole antennas are enclosed. Wherever the Committee uses the term ‘antennas’ in this report it is referring to such boxes. The characteristics of the radiation beam are detailed in Chapter 6.
- An equipment cabinet with a power supply and the actual transmitter.
- Cables which provide the energy and transfer the signal between the transmitter and the antennas.

The following can be present dependent of the construction:

- A supporting structure for the antennas (e.g. a mast).
- A dish-shaped antenna that provides a microwave link with another base station.
- A connection, in the equipement cabinet, to the ground-based (cable) network and an associated cable connection.

Not all base stations have a direct connection to the ground-based network. In urban areas, where many base stations are located within close proximity of each other, several base stations can function as a collection point. By means of a microwave link they are connected to various other base stations in the area. The outward appearance of base stations varies considerably. Sometimes efforts are made to help the station blend in with its surroundings.

In thinly populated areas the antennas are often placed on a free-standing purpose-built mast of between 20 and 35 m in height. A short mast can sometimes be mounted on a crane as a temporary measure. A special situation is a mast camouflaged as a tree.

In urban areas and rural areas without any tall obstacles, antennas are often mounted on short masts located on the roof of a building or against an outer wall such that the mast protrudes above the edge of the roof, or on a highway portal.

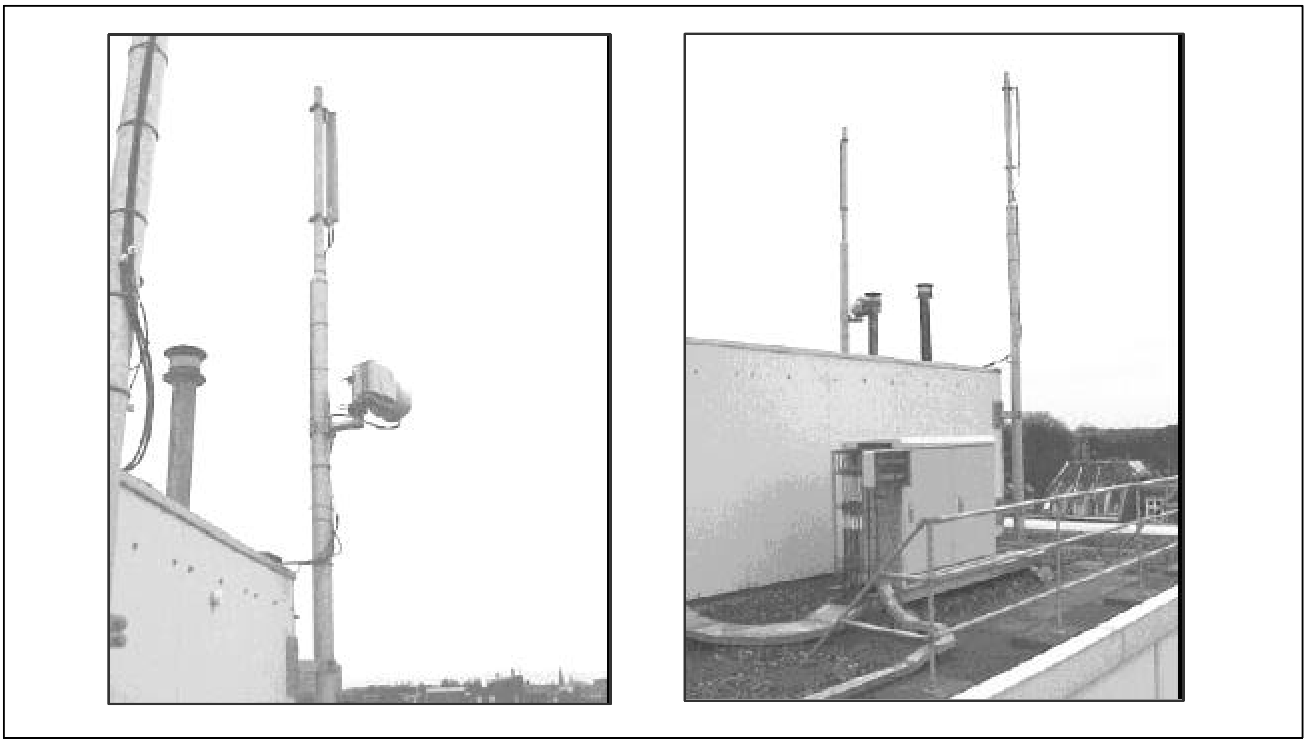

Figure 1 A base station; right: two of the three masts with an antenna at the top; foreground: the equipment cabinet; left: one of the masts with an antenna and a dish antenna for the microwave link.

Antennas are also sometimes mounted directly onto an outer wall, in clock towers behind belfry windows, on large advertising boards or on electricity pylons.

2.3 Network

A GSM 900- or DCS 1800 network is constructed as a cellular structure. Each base station serves a limited area around it, termed a cell. A certain number of frequency bands is used within each cell. Neighbouring cells cannot make use of the same frequency bands, because at a cell boundary there is always some overlap between the areas covered.

Depending upon the size of the area covered, a cell is referred to as a macrocell, a microcell or a picocell. Macrocells cover an area with a radius of several hundred metres to ten kilometres. In heavily populated urban areas the cell is relatively small. This is due, in particular, to the demand for capacity: because each station has a limited capacity, more base stations are needed in urban areas and the cells are smaller. Due to the limited range the emitted power of base stations within smaller cells is correspondingly lower. Therefore, as the number of base stations increases, the total transmitted power virtually remains the same due to the relatively low capacity of base stations in small cells.

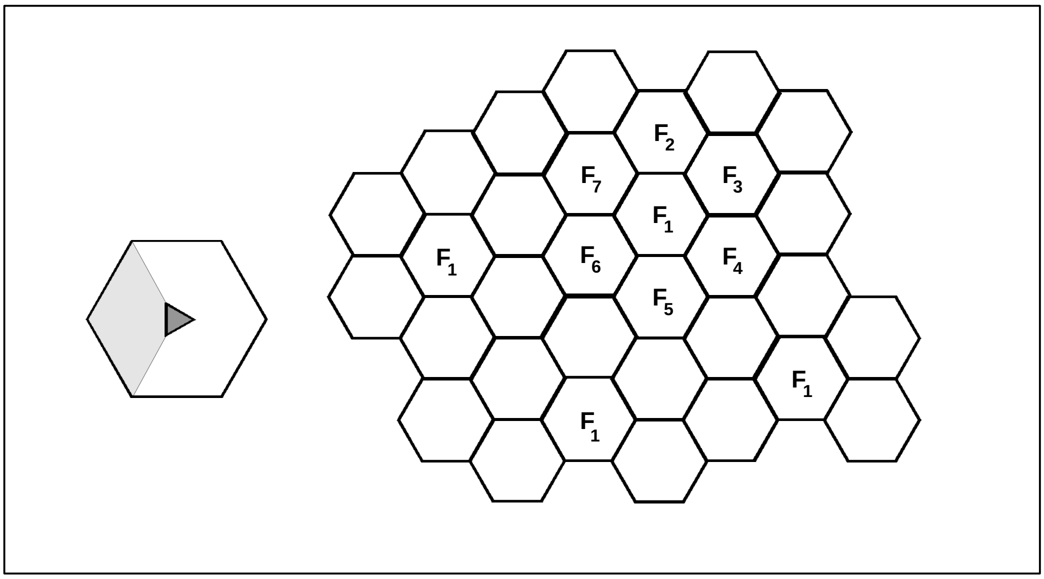

Figure 2 Schematic representation of a network's cellular structure. Neighbouring cells have different frequencies (F_1 through F_7). On the left: the position of the base station within the cell and the area covered by one antenna.

Microcells are generally installed in places where there is a large number of people within a limited area, for example, in shopping centres and at train stations. The range of a microcell is usually not more than several hundred metres. Due to the limited area covered the antennas are mounted relatively low and have a low power.

Picocells are used inside industrial and office buildings. The antennas have a very limited range of no more than a few dozen metres and are generally mounted on the wall, close to the ceiling. They have a very low power which is comparable to that of the base stations used in home-based portable phones, such as DECT phones.

Reducing the cell size reduces the distance between base station and the mobile phone. As telephones are constructed such that they always transmit using the lowest possible power, a smaller cell size will result in the transmitted power and field strength around the phone being lower than within larger cells.

Chapter **3**

Health aspects

The Committee has based this overview mainly on several review articles and reports which have been published in recent years. Wherever possible, the most up to date information has been used.

Biological effects arising from exposure to radiofrequency electromagnetic fields can be categorized in a variety of ways. The most common distinction is that between thermal and non-thermal effects. For thermal effects, the development of heat plays a role, whereas in the case of non-thermal effects it does not.

3.1 Thermal effects

The effects due to the development of heat in biological material caused by radiofrequency electromagnetic fields, are the only health effects that have been scientifically established. The consequences of heat development in cells, organs and organisms is well-understood. The Health Council report published in 1997 has already provided an overview of this (HCN97). A more recent overview that concurs with the Health Council report with respect to the description of thermal effects is that compiled by an Expert Panel of the Canadian Royal Society (RSC99). Both reports conclude that in the case of the entire body being exposed to an energy uptake, expressed as the Specific Absorption Rate (SAR), of less than 4 W/kg no health problems occur. In a recent publication, D'Andrea provides an overview of behavioural experiments with animals which found that the lower threshold for behavioural changes also is approximately 4 W/kg (D'An99).

If only parts of the body are exposed, a higher SAR is generally acceptable. In the Canadian report some doubts are expressed regarding the higher limit values permitted in Canada for exposure of the head. According to the committee who compiled the report, the limit of 8 W/kg deemed acceptable for occupational exposure may in fact provide insufficient protection against eye damage.[a] Generally speaking, only whole-body exposure occurs within the vicinity of GSM 900 and DCS 1800 base stations. This is, therefore, the assumption upon which the Committee bases this report. The limits set are accordingly much lower than would be the case if only parts of the body were exposed.

3.2 Non-thermal effects

Much of the recent concern about possible health effects associated with mobile telephony is related to non-thermal effects. Many of these effects were already considered in the Health Council's 1997 report (HCN97). The Canadian Royal Society's report (RSC99) mentioned in section 3.1 and a recently published report from an Advisory Committee in the United Kingdom (IEG00) contain an extensive overview. This report briefly reviews the most important elements. The Committee points out that the physical processes which possibly underlie each of these effects are poorly understood.

3.2.1 Effects on cell membranes

Various studies have demonstrated that exposure to radiofrequency electromagnetic fields can affect the transport of calcium, sodium and potassium ions through the cell membrane. In many cases it cannot be excluded, or it is indeed extremely likely, that this is a thermal effect. *In vitro* studies on calcium transport also demonstrated that low-frequency modulation of the radiofrequency signal was associated with changes to this ion transport.

It is not known whether this kind of effects result in changes to the functioning of the cell. Nor is it known whether in an intact organism, which is a much more complex system than a single layer of cultured cells, such membrane effects occur and whether these could eventually result in health effects.

[a] The eye has only very limited capabilities for disposing of added warmth, due to its limited blood circulation. As a result, its temperature can quickly rise to a damaging level.

The results of these studies are for the most part ambiguous. They provide no indications for possible threshold values or exposure-response relationships.

3.2.2 *Genotoxicity and carcinogenesis*

In a recent publication, Brusick et al. provide an overview of *in vitro* genotoxicity data, i.e. data about damage to the DNA, the genetic material, which can form a step in the development of cancer (carcinogenesis) (Bru98). In the analysis, the quality of the research was an important factor. The authors conclude that there are no strong indications that radiofrequency electromagnetic fields between 30 MHz and 300 GHz cause DNA damage. Where effects were found, i.e. at relatively high field strengths, these were most likely the result of thermal processes. No effects whatsoever have been found at the field strengths present in the vicinity of GSM 900 and DCS 1800 base stations.

The conclusions of the Canadian and UK reports (IEG00, RSC99), which are in part based on more recent data, concur on this matter. These reports also contain extensive reviews of relevant *in vivo* research results. These studies also found no effects at the very low field strengths present near base stations. Where effects have been found at high field strengths, the picture they provide is inconsistent and difficult to interpret.

Elwood gives a thorough and critical overview of the epidemiological data concerning a possible relationship between exposure to radiofrequency electromagnetic fields and the occurrence of cancer (Elw99). The picture obtained in this case is also inconsistent. Furthermore, the quality of the studies is somewhat questionable, especially those where the correlation would appear to be the strongest. None of the studies were carried out using subjects living near base stations. The most relevant studies concern possible effects due to living near radio and television towers. The most extensive of those studies were carried out in Australia and England. In both countries it was apparent from an initial, preliminary study that there might be a slight increase in the risk of leukaemia and several other forms of cancer within the immediate vicinity of the towers (Dol97b, Hoc96). According to more extensive studies, in Australia in a larger area around the transmitter complex (Hoc99, McK98, McK99) and in England at additional transmitters sites (Dol97a), the previously found link did not exist. The Committee subscribes to the conclusion in Elwoods review, namely that the epidemiological data do not indicate the existence of a possible link between exposure to radiofrequency electromagnetic fields and cancer.

The Committee concludes that the genotoxicity and carcinogenicity data do not indicate any health risk for the field strengths to which the general public will be exposed in the vicinity of GSM 900 and DCS 1800 base stations.

3.2.3 *Effects on brain functions*

The previously mentioned Canadian and English reports provide an extensive review of the various effects which radiofrequency electromagnetic fields can have on brain function.

A relationship to various clinical disease symptoms, such as seizures, epilepsy and Alzheimer's disease, has not been found.

In several studies a possible relationship between exposure to radiofrequency electromagnetic fields and sleeping disorders has been investigated. The results indicate that exposure to the relatively high field strengths of mobile phones (which may be 50 to 100 times higher than the field strengths in homes in the vicinity of base stations) can affect brain activity during the sleeping cycle. The natural electrical activity in the brain shows a highly characteristic cyclical wave pattern during sleep. Exposure to external electromagnetic fields can result in changes to this pattern. At low field strengths, however, indications for such an effect have never been found. In the Committees view it is unlikely that these effects will occur at the very low field strengths present near base stations. All the same, the effects on the sleeping pattern did not lead to health complaints in any of the volunteers studied. Indeed the effect was sometimes positive, as during exposure volunteers fell asleep more quickly and woke up less often (Bor99).

Complaints about sleeping disorders were however found in a study on people living in the vicinity of a shortwave transmitter station at Schwarzenburg in Switzerland. The Committee has examined the final report of this study and has doubts about both its design and implementation (Alt95). It is of the opinion that the data in the report insufficiently substantiates the link between exposure to radiofrequency fields from the shortwave station and the occurrence of sleeping disorders or other non-specific health problems.

Headache is another non-specific complaint which is sometimes linked to exposure to radiofrequency electromagnetic fields. There are, however, no research results which can substantiate the existence of a causative link. The Committee is also not aware of any plausible biological mechanism which could explain such a link, and the fact that there are many causes of headache must be taken into consideration. It could very well be the case that uncertainty over and a lack of understanding about ‘radiation’ emitted by mobile phones and base stations results in psychological stress that causes headache. In section 3.2.4, the Committee further considers psychosomatic symptoms.

A final symptom to be discussed is the possible influence of exposure to radiofrequency electromagnetic fields on cognitive functions such as memory, reaction time and concentration. In a study by Preece et al. (Pre99), healthy volunteers were exposed to GSM 900 signals from a mobile phone. Out of a series of 15 different tests, one demonstrated a significant positive change: in one of the reaction time tests the reaction time increased by 3%. In a study of comparable design by Koivisto et al. (Koi00), 12 cognitive tests were carried out. Three of these showed a significant change in the function tested. However, the Committee feels that the statistical processing of the results is incorrect and accordingly cannot subscribe to the author's conclusion that an effect has been established. Furthermore, the positive tests in both studies are different. In a study by Freude et al. (Fre00), which also examined exposure to electromagnetic fields originating from a GSM 900 mobile phone, no effect was observed in three cognitive function tests, but an effect in spontaneous electrical brain activity was found. In the most demanding of the three function tests slight changes in slow brain potentials were measured.

The Committee concludes that a direct effect of exposure to radiofrequency electromagnetic waves on cognitive functions cannot be excluded but that the effects observed until now are slight and reversible. In the Committee's view more well-designed studies are needed to ascertain the nature and size of these effects. On the basis of the present data, the Committee concludes that the occurrence of health problems at exposure levels associated with the use of mobile phones is unlikely. It is considered virtually impossible that the low field strengths in the vicinity of base stations give rise to changes in cognitive functions.

3.2.4 Psychosomatic effects

Notwithstanding the above-mentioned, there are clear indications for the existence of an association between the occurrence of non-specific complaints and living within the vicinity of a base station or other types of antenna installations. It is plausible that fear of electromagnetic fields (‘radiation’) is a contributory factor. A substantiation of this proposition can be found in a review article about studies into the relationship between subjective health complaints (‘electromagnetic hypersensitivity’) and exposure to electromagnetic fields (Ber97). Here the conclusion was drawn that there is no link between the occurrence of complaints and the strength and frequency of the electromagnetic field in question. Furthermore, the results are often contradictory and inconsistent and there is no known biological mechanism which could explain them.

Studies into the effects of ionizing radiation and exposure to toxic substances provide strong indications that people who fear exposure to health damaging agents can experience complaints which they attribute to such exposure. They can also attribute existing complaints or illnesses to the (actual or suspected) exposure and they can show a selective sensation of physical symptoms and associate these with the exposure. On the basis of strong correlations between the occurrence of such complaints or attributes and levels of stress, including psychological stress, it is assumed that these are psychological effects (Hav99). It is not inconceivable that such effects also occur upon exposure to electromagnetic fields and that the perception of the risk associated with this exposure is a contributory factor in the emergence of such effects (Mat98, Ren97).

3.3 Electromagnetic compatibility

In the treatment of certain categories of patients, increasing use is been made of implantable medical devices, such as pacemakers, other sorts of stimulators and insulin pumps. It is important that such devices continue to function under all circumstances without disruption. Were this not the case, negative health effects could arise. Therefore, the Committee has given consideration to the possible disruption that could occur to such devices due to electromagnetic fields.

Electromagnetic compatibility (EMC) is the capacity or property of an electrical or electronic device to function satisfactorily in its electromagnetic environment without adding unacceptable interfering signals to it (IEC89). I.e.: devices may themselves cause no interference and must possess sufficient insensitivity (immunity) to interference. In 1992, the EMC Directive 89/336/EEC from the European Community was put into force in order to have some degree of certainty that the immunity requirement was being met (COC89)[a]. On the basis of this directive, the manufacturer is required to both ensure and demonstrate that his devices are sufficiently immune. The EMC Directive is a horizontal (general) directive. For specific groups of devices, other directives may apply. This is the case for, e.g., medical devices (93/42/EEC) and active implantable medical devices (90/385/EEC) (COC90, COC93).

For medical devices, a harmonized EMC standard of 3 V/m has been drawn up for the frequency range 26 MHz to 1 GHz (IEC93)[b]; this standard takes account of the relevant European directive. The standard is however not applicable to frequencies

a European Guidelines are mandatory and are to be implemented in national legislation.

b Such standards are voluntary in nature and serve as an aid in determining whether the essential requirements stated in the guidelines have been satisfied.

above 1 GHz, although increasing use is being made of this part of the electromagnetic spectrum, for example by the DCS 1800 system. This makes demonstrating immunity in this frequency range more difficult.

With regard to implanted medical devices, European directive 90/385/EEC details specific requirements for immunity. These requirements are further elaborated in technical standards that establish to which minimum field strengths these devices must be immune. These minimum field strengths are on the one hand higher than the field strengths in the aforementioned general immunity requirements for medical devices and on the other hand higher than the exposure limits based on health considerations such as those of the Health Council and the ICNIRP (HCN97, ICN98). Therefore, if these health-based guidelines are satisfied, it is unlikely that interference will occur in the medical implants concerned. Again, the technical standards set no requirements for frequencies above 1 GHz. It is however not unreasonable to assume that at frequencies not much higher than 1 GHz the device has an immunity comparable to frequencies under 1 GHz.

Recently, the Netherlands Organization for Applied Scientific Research (TNO) carried out an extensive study into the effects of electromagnetic fields on medical devices such as insulin and infusion pumps (Hen00). The results of this study give no reason to assume that the proper functioning of these devices would be disrupted in residential areas in the vicinity of a base station. On the basis of other publications, the same is true for pacemakers. However, the Health Council report of 1997 advised a minimum distance of 15 cm between a switched-on mobile telephone and an implanted pacemaker. It seems advisable to adhere to this advice for the time being.

The possibility exists that ambulant medical devices (i.e. not medical implantations) which satisfy the EMC standards, could experience a disruption to their normal functioning in an environment with a field strength below the health-based exposure limit. This could, for example, occur if such devices come within the immediate vicinity of transmitting equipment. The aforementioned TNO report confirms earlier findings that at a short distance, switched-on mobile telephones can in certain cases disrupt the functioning of such medical devices. In the Committee's opinion this problem can best be tackled by effectively informing the public through the users' instructions for both mobile phones as well as medical devices.

Chapter 4

Precautionary principle

The request for advice asked for an indication as to the extent to which there is cause, on the basis of the precautionary principle, for stricter standards than those based on thermal effects. The precautionary principle is explicitly laid down in the EU treaty and is one of the starting points of its environmental policy. This is also the case within the Netherlands. However, in part based on jurisprudence from the Court of Justice of the European Community, the precautionary principle is also applied to other policy areas, including public health.

For the information of the member states, the European Commission made an statement in February 2000 regarding the use of the precautionary principle (Com00). In this statement, the Commission indicates that the principle should be applied where there is a *reasonable suspicion* of the existence of a health or environmental risk. Furthermore, the Commission indicates that measures based on the precautionary principle should not be aimed at completely precluding any risk; it assumes that such an effort is unrealistic. In the present report, the Committee takes a pragmatic approach and seeks to establish whether there are reasonable grounds for suspecting the existence of a health risk as a consequence of non-thermal effects, that could lead to application of the precautionary principle.

In the *Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)* (CEU99) the following comment is made in Appendix 1:

However, since there is a safety factor of about 50 between the threshold values for acute effects and the basis restrictions, this recommendation implicitly covers possible long-term effects in the whole frequency range.

The Committee cannot subscribe completely to this approach, as, with respect to the application of the precautionary principle, it distinguishes between thermal and non-thermal effects.

4.1 Thermal effects

Thermal effects have been scientifically established (see section 3.1) and form the basis of the current exposure limits. Safety margins have been incorporated in the determination of these exposure limits. In itself, this cannot be regarded as an interpretation of the precautionary principle in the sense in which it is used in the European Commission's statement (Com00). Yet this approach contains a certain element of precaution, as the safety margins are intended to provide a high level of protection to all members of the population, including those who possibly have a less effective thermoregulatory mechanism than the healthy adults from whom the experimental data were obtained. Due to the application of the safety margins, the final exposure limits obtained are such that it can be reasonably assumed that no health risks exist for exposure to field strengths under these limits. It is, therefore, not necessary to apply the precautionary principle to thermal effects.

4.2 Non-thermal effects

The scientific literature reveals that in *in vitro* experiments and animals studies, sometimes effects of exposure to radiofrequency electromagnetic fields are found, that most likely cannot be explained by temperature changes. However, there is not a single case where such short-term biological effects have resulted in either short-term or long-term health damage. The human body has a large capacity to compensate for a variety of external effects, such that no health problems arise. Furthermore, it is also capable of physiological adaptation. Were this not the case, the average life span would be considerably shorter than it currently is, as in everyday life, people are continually exposed to artificial, but especially to natural potentially harmful substances, radiation and threats of a biological nature. A biological effect does not always, therefore, result in a harmful health effect.

An important question is whether or not there are indications for the existence of a relationship between exposure to radiofrequency electromagnetic fields and the development of cancer. In section 3.2.2 the Committee concluded that the data available provided no indication for the existence of a causative link.

The suspicion that a large range of health problems, which are often non-specific, could be the result of exposure to radiofrequency electromagnetic fields originating from base stations or mobile phones, is frequently expressed. The complaints often concerned are headache, insomnia and disruptions to concentration. Such complaints can arise due to a variety of causes. In the previous chapter, sporadic, unequivocal data were described, which indicate the possible influence of radiofrequency electromagnetic fields on certain brain activities.

The Committee is of the opinion that it cannot be reasonably presumed that any of the three categories of non-thermal effects concerned, namely, biological effects, carcinogenesis and non-specific complaints, pose a health threat. Thus, owing to the Committee's pragmatic approach to the ministers' question as to whether or not there is cause, on the basis of applying the precautionary principle, to establish exposure limits at a lower level than the values based on thermal effects, its answer is in the negative. However, as indicated in section 1.2, the decision as to whether or not to apply the precautionary principle is first and foremost a political one. In view of the remaining questions and in view of the increasing exposure of the public to electromagnetic fields, caused by, e.g., mobile telephony, the Committee argues the case for further research into non-thermal effects possibly caused by such fields.

Chapter **5**

Exposure limits

In the previous chapters, the Committee has demonstrated that it sees no cause for changing the present exposure limits. It therefore upholds the recommendation for exposure limits given in the reports *Radiofrequency electromagnetic fields (300 Hz – 300 GHz)* and *Electromagnetic fields (0 Hz – 10 MHz)* (HCN97, HCN00).

The previous chapter mentioned the *Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)* (CEU99). This recommendation contains exposure limits for the general public based on guidelines such as those drawn up by the ICNIRP (International Commission on Non-Ionizing Radiation Protection) (ICN98). For certain aspects, these guidelines deviate from those given in the Health Council recommendations of 1997. The basic restrictions in the frequency range which covers the frequencies at which mobile telephony operates are the same: a maximum energy uptake, expressed as Specific Absorption Rate, SAR, of 0.4 W/kg for occupational exposure and a SAR of 0.08 W/kg for the general public, averaged over each arbitrary exposure period of six minutes. With reference to the derived values, which are used in daily practice, the ICNIRP and the Health Council differ in their recommendations, because in the frequency range from 10 GHz tot 300 GHz there are differences in the basic restrictions which affect lower frequencies. These differences have a two-fold cause.

The first one is that, for the frequency range between 10 GHz and 300 GHz, the ICNIRP proposes a power density of 50 W/m^2 as the basic restriction, whereas the

Health Council advises 100 W/m^2. The Health Council's advised value is consistent with the recommendations of other organizations (IEEE92, NRPB93) and with international guidelines for exposure to electromagnetic fields with frequencies higher than 300 GHz (such as infrared radiation) (Ron98). The only rationale ICNIRP provides for the lower value is that it wishes to pursue a ‘conservative approach’.

The second cause for the differences between the ICNIRP and Health Council guidelines is the fact that for the full frequency range of 10 GHz to 300 GHz the ICNIRP makes the same distinction between exposure limits for the general public and for workers, whereas the Health Council makes a distinction which decreases with increasing frequency and at 300 GHz no longer exists. This is because at frequencies above 300 GHz no differentiation is made between the two groups, and it is therefore not logical to have a sudden change in the exposure limits for the general public at 300 GHz.

As the Committee takes the view that the recommendations issued by the Health Council in 1997 are more logical and consistent than those of the ICNIRP from 1998 (and thus more logical than those of the Council of the European Union from 1999), it adheres to the recommendations from the report *Radiofrequency electromagnetic fields (300 Hz - 300 GHz)* (HCN97). For the frequencies at which GSM 900 and DCS 1800 mobile phone systems operate, the exposure limits are detailed in Table 2. For comparative purposes the ICNIRP recommendations are also shown.

Table 2 Exposure limits for 900 MHz and 1800 MHz.

			basic restrictions	reference levels		
			SAR (W/kg)	electric field (V/m)	magnetic field (A/m)	magnetic flux density (µT)
900 MHz	workers	Health Council	0.4	109	0.29	0.36
		ICNIRP	0.4	90	0.24	0.3
	general public	Health Council	0.08	49	0.13	0.16
		ICNIRP	0.08	41	0.11	0.14
1800 MHz	workers	Health Council	0.4	180	0.47	0.6
		ICNIRP	0.4	127	0.34	0.42
	general public	Health Council	0.08	81	0.22	0.26
		ICNIRP	0.08	58	0.16	0.2

These values apply to the frequencies at which the information exchange between the base stations and the mobile phones occurs. Base stations can be interconnected by microwave links. These operate in the 24 to 40 GHz frequency range. Exposure limits for these frequencies are detailed in Table 3.

Table 3 Exposure limits for frequencies between 10 GHz and 300 GHz.

			basic restrictions	reference levels			
			power density (W/m^2)	electric field (V/m)	magnetic field (A/m)	magnetic flux density (µT)	
10-300 GHz	workers	Health Council	100	194	0.52	0.65	
		ICNIRP	50	137	0.36	0.45	
	general public	Health Council	20	$49.5 \times f^{0.24}$ [a]	$0.13 \times f^{0.24}$ [a]	$0.17 \times f^{0.23}$ [a]	*f* in GHz
		ICNIRP	10	61	0.16	0.2	

[a] In HCN97 an incorrect formula was stated.

The exposure limits for the electric field strengths are illustrated in Figure 3, in which a comparison with the ICNIRP guidelines is also made.

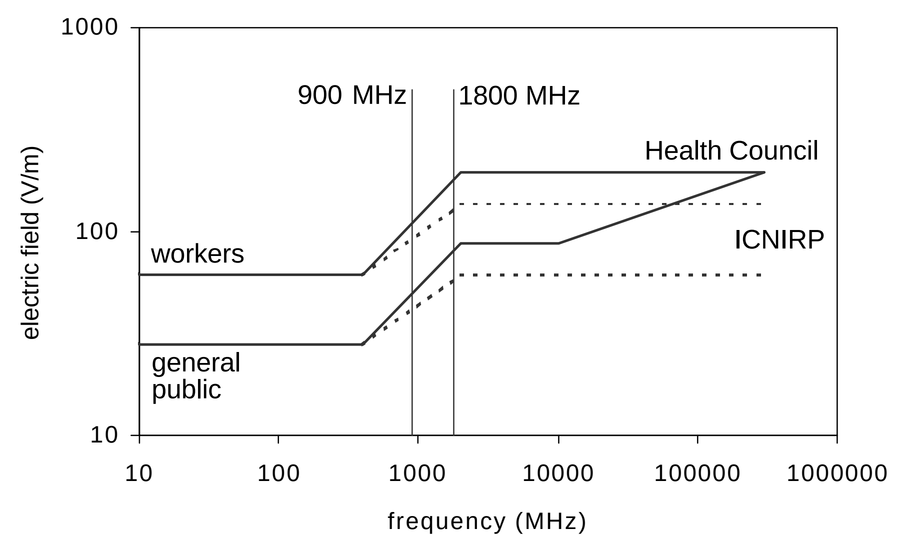

Figure 3 Reference levels as given by the Health Council (continuous lines) and the ICNIRP (dotted lines), for workers and the general public.

Chapter 6

Field strength levels near base stations

6.1 Antennas

6.1.1 Main beam characteristics

The antennas transmit the electromagnetic fields mainly in a forward horizontal direction in which the beam is targeted at a downward angle of between 3 and 6 degrees. In the most usual construction of a base station there are three antennas. In such a case the beam from each antenna has a horizontal spread of 120^o (Figure 4), such that the three antennas cover an entire circle.

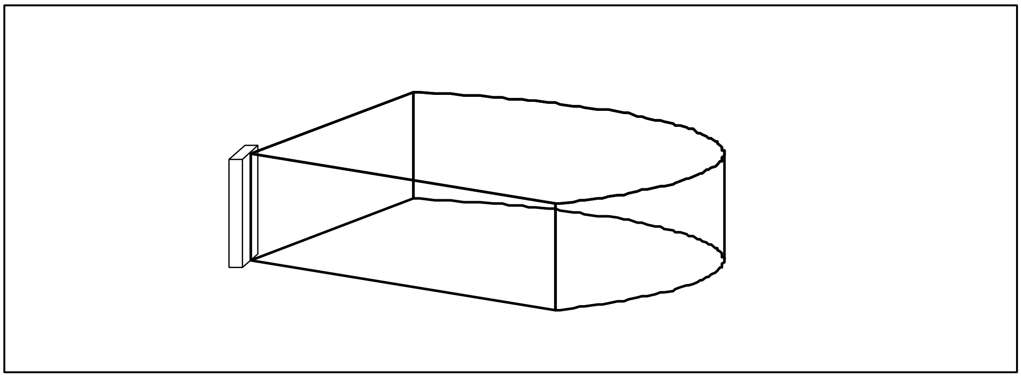

Figure 4 Schematic representation of an antenna's main beam.

6.1.2 *Field strength within the beam*

The field strength within the beam depends upon the power of the antenna and the distance from the antenna. Close to the antenna, in the near-field, there is no linear relationship between the field strength and the distance, but in the far-field there is. The dimension of the source is important for the calculation of the boundary between the near- and far-field (HCN97).

For the antennas most typically used at base stations, the near-field remains limited to a distance of several metres from the antennas. Within the near-field, the field strength outside of the beam strongly decreases as the distance to the beam increases. Simple calculations reveal that for an antenna with a radiated power of about 20 Watts, a representative value for the antennas used in the Netherlands, the exposure limit for the general public can only be exceeded within the beam and at a distance of no more than 3 metres from the antenna. Figure 5 provides a schematic representation of the calculated field strengths mentioned.

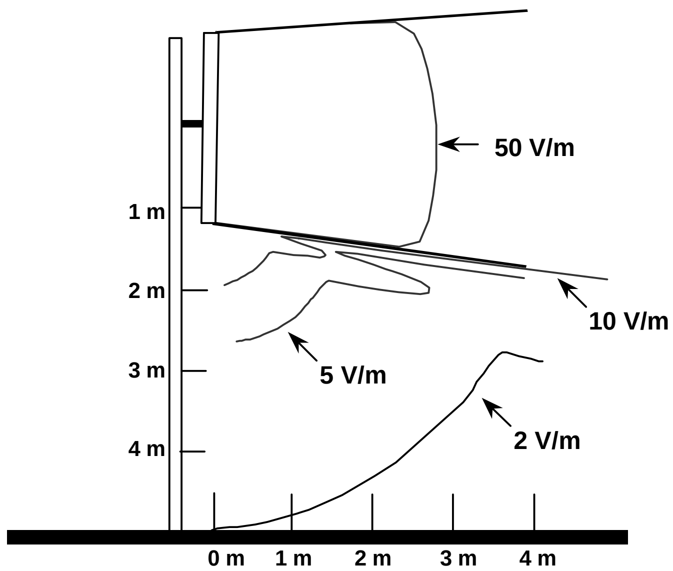

Figure 5 Schematic representation of the field strengths near a GSM 900 antenna with a radiated power of about 20 W.

6.1.3 Field strength outside the beam

The field strengths outside the beam are considerably lower than those in the beam and the exposure limits are not exceeded (see also Figure 5).

From measurements that have been carried out at various locations near GSM 900 and DCS 1800 antennas, it is clear that outside the beam at a distance of 1 to 1.5 m underneath the beam and at a distance of less than about 3 m from the mast the field strength is not greater than 3 V/m. At distances further from the beam and the antenna the field strength is inversely proportional to the distance. At most of the accessible places on the roof, the field strengths are generally lower than 1 V/m. Annex C details an example of field strength measurements in the vicinity of a base station.

As a consequence of the protective effect of roof constructions, the field strength in the space underneath the roof is lower than that on the roof surface. A variety of different measurements reveal this to be lower than approximately 0.2 V/m.

At distances further from the antenna (for example at street level) the field strength will also be considerably lower than 1 V/m. The actual field strength will vary with respect to time and place. On the one hand, this is because the transmitted power of a GSM 900 or DCS 1800 antenna depends on the demand for capacity (which in itself is a function of the number of calls being made at any given time). On the other hand, the relative contribution of other sources at a greater distance from the base station is increasing. In all cases the exposure level lies considerably below the exposure limit.

6.2 Dish antennas

6.2.1 Main beam characteristics

The antenna transmits electromagnetic fields at a frequency of between 24 and 40 GHz within a very narrow beam. The opening angle is not more than about 3^o. The beam is therefore comparable to the light beam from a laser.

6.2.2 Field strength within the beam

The power of the dish antenna used at base stations is not more than approximately 130 mW. The maximum power density for such antennas is four times the quotient of the available power and the surface of the antennas. Within the main beam it occurs within a distance from the antenna corresponding to one eighth of the far-field distance

(Pey61). The far-field distance varies between 14.4 m at 24 GHz and 24 m at 40 GHz. The maximum power density therefore occurs within 1.8 to 3 m from the antenna.

For an antenna with a diameter of 30 cm and a maximum power of 130 mW the maximum power density is 7.4 W/m^2, which corresponds to an electric field strength of 52.7 V/m. For the general public, the exposure limit is 20 W/m^2, or at least 106 V/m (for a 24 GHz transmitter). Even within the beam, the exposure limit is not exceeded. Furthermore, the likelihood of someone being present within the beam is small, as the beam is narrow, and in the usual position (affixed to a mast) it remains out of the reach of the general public.

6.2.3 *Field strength outside the beam*

Outside the beam, the field strength at all points is considerably lower than within the beam and thus also considerably lower than the exposure limit.

For distances from the dish antenna greater than half of the far-field distance, the electric field originating from the antenna is inversely proportional to the distance from the antenna. The electric field strength is simple to calculate in this case. Table 4 shows the result of a calculation of the field strength outside of the main beam and at a distance of 4 m from the dish antenna.

Table 4 Electric field strengths outside the main beam at a distance of 4 m from a dish antenna with a capacity of 130 mW.

number of degrees outside the main beam	electric field strength (V/m)
5^o	< 3.6
20^o	< 1.5
50^o	< 0.5
100^o	< 0.15

Chapter **7**

Low-frequency sounds and vibrations

It has been suggested that some of the complaints from residents of buildings where an antenna installation is located could be due to low-frequency sounds or vibrations that originate from the equipment cabinet, or movements of the mast construction or its securing cables caused by the wind.

The Committee, on the basis of verbal reports, is aware that in some cases changes to the equipment cabinet did lead to a reduction of complaints. However, insofar the Committee is aware, this has not been documented in writing. Furthermore, no data concerning such cases has been found within the scientific literature.

The Committee is of the opinion that in dealing with complaints, the question whether or not low-frequency sounds or vibrations play a possible role must be investigated.

Chapter 8

Conclusions and recommendations

The Committee adheres to the exposure limits proposed in the report *Radiofrequency electromagnetic fields (300 Hz – 300 GHz)* (HCN97). The scientific data concerning non-thermal effects, which include the results of epidemiological studies into a possible link between exposure to radiofrequency electromagnetic fields and the occurrence of cancer, do not, in the Committee's opinion, give cause for the current exposure limits to be lowered. This is because the indications that non-thermal effects could give rise to health problems are too weak.

The exposure limits are particularly important in situations where people may find themselves within the immediate vicinity of an antenna.

8.1 General public

The Committee considers the likelihood of health problems arising in work and residential areas near GSM 900 and DCS 1800 base stations due to exposure to electromagnetic fields originating from the antennas, extremely small. The field strengths are always considerably lower than the health-based exposure limits proposed by the Health Council and other organizations. The Committee would like to indicate that even in the countries where the exposure limits have been lowered using the precautionary principle, namely Italy and Switzerland, the resulting limits of 4 - 6 V/m are not exceeded in spaces underneath base stations.

Disruption to medical implants or other medical devices due to electromagnetic fields originating from base stations can, as long as the relevant European immunity requirements are satisfied, effectively be ruled out. However, further research into possible disruption caused by portable communication devices, such as mobile phones, is desirable. The Committee will come back to this point in a subsequent and more extensive report.

On the roof surface, the field strengths in the vicinity of a base station are generally higher than in the spaces beneath the roof. If the antennas are mounted several metres above the roof surface, the field strengths for persons on the roof will always remain below the exposure limits for the general public. Where there is doubt, the level should be verified by means of measurement.

As a rule of thumb, it can be taken that in the open, the minimum distance to the antennas within the main beam should be 3 m and outside the beam 0.5 m. For most antennas this does indeed provide an extra margin of safety, but it is simpler and more practical to keep the same distance than to let the distance vary in accordance with the antenna’s power. As antennas effectively do not emit any radiation to the rear, this fact combined with the absorptive character of the wall is, in the case of antennas mounted to an outer wall, sufficient for the thickness of the wall to be adopted as the minimum distance.

Wherever it is possible for someone to come within the aforementioned minimum distance from an antenna, measures should be taken to prevent this from happening.

8.2 Occupational exposure

With regard to occupational exposure, no special measures are needed for exposure at a distance of more than 10 cm from the top, bottom or backside of the antenna or from the main beam. If this distance is shorter or if it is necessary for someone to be in the main beam close to the antenna, safety precautions need to be taken.

8.3 Complaints

8.3.1 Health

The Committee is of the opinion that residents should always be involved at the earliest possible stage, i.e. already during the planning phase, in the construction of a base station. Adequate information can prevent health complaints among people living near a base station, because such complaints will mainly arise as the result of fear of the unknown, especially if radiation also plays a role. Should complaints occur, these should always be taken seriously. Even at later stages, providing adequate information can solve a great deal of problems.

In the case of persistent complaints, it might be investigated whether or not low-frequency sounds or vibrations play a role.

8.3.2 Interference

For the current field strengths in living accomodations in the vicinity of base stations, disruption to medical or other electrical or electronic equipment can almost be ruled out, as long as the equipment meets the requirements of the European immunity guidelines. If, despite this, disruptions occur (and that will almost certainly be the case only for non-medical electronic devices), this must of course be remedied as quickly as possible. The Interference Complaints Regulation provides sufficient guidance with respect to this (Stc 99).

8.4 Laws and regulations

At present, there is no legal possibility within the Netherlands for controlling the mounting of antennas (and thus base stations) in accordance with health considerations. The Committee recommends that, in line with the European R&TTE directive (Radio and Telecommunications Terminal Equipment) (Eur99), such a possibility is created. This can for example be accomplished by amending the Telecommunications Act or the Environmental Management Act.

8.5 Monitoring and enforcement

The Committee recommends that in the very near future clarity be provided with regard to the division of responsibility concerning the monitoring of the set-up of base stations, the monitoring of the field strengths transmitted by antennas and the enforcement of the relevant legislation. Further pronouncements regarding this are not within the Committee’s remit but the Committee points out that interference and other problems are easier to solve, and indeed can often be prevented, if the general public knows which organization it should turn to.

8.6 Central registration of technical data

In the light of what was stated in the previous paragraph, the Committee proposes that the technical data, a field strength calculation and the results of possible measurements should be registered centrally. The German approach can be taken as an example: in Germany it is a legal requirement that each antenna installation be registered with the authorities and that this registration be accompanied by a ‘location certificate’ (Standortbescheinigung) that is issued by the Regulierungsbehörde für Post und Telekommunikation and which contains all of the aforementioned details about the installation (BMPT 97).

The Hague, 29 June 2000,
on behalf of the Committee

(signed) Dr E van Rongen, secretary	(signed) Dr EW Roubos, chairman

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A The request for advice

B The committee

C Field strengths in the vicinity of a base station

D Summating field strengths of different frequencies

Annexes

Annex **A**

The request for advice

In September 1999, the President of the Health Council received the following request from several ministers (letter reference DGM/SVS/99207094):

Dear Mr Sixma,

In January 1997, the Health Council published a report about the health effects of radiofrequency electromagnetic fields from 300 Hz to 300 GHz. One of the conclusions of this report was that the available data did not indicate that the use of mobile phones resulted in detrimental health effects.

Since then there has been an enormous increase in the use of mobile phones and within the general public concerns have been expressed about the possibility of detrimental health effects. This applies to both the use of mobile phones and the antenna installations which are often located in residential areas. These concerns have in part arisen as a result of various studies, and reports about them in the media, which have alluded to the possible detrimental health effects of electromagnetic fields arising from the use of mobile phones and the associated antenna installations.

We hereby request you, also on behalf of the State Secretary for Transport, Public Works and Water Management, to give in the near future an overview of the scientific literature relevant to mobile telephony that has been published since your last report in 1997 and to state the conclusions and recommendations that the Health Council arrives at based on this literature. Of particular importance is the question as to what extent, on the basis of current insights, non-thermal effects can affect health, and, from a scientific point of view, to what extent this gives cause, in the sense of the precautionary principle, to adopt more stringent standards than those based on our knowledge of thermal effects.

Furthermore, in connection with section VI of the Recommendation of the Council of the European Union concerning limiting the exposure of the general public to electromagnetic fields (see enclosure), we request you to provide an overview of recent relevant scientific literature, published since your report, concerning the health effects of radiofrequency electromagnetic fields in general. In so doing, we request you to indicate which conclusions you accept and in the Health Council’s view what the most important gaps in our current knowledge are. Research currently being carried out at an international level should be included. We would also like your recommendations in this regard.

The Minister of Housing, Spatial Planning and the Environment,
(signed) J.P. Pronk

The Minister of Health, Welfare and Sport,
(signed) Dr E. Borst-Eilers.

Annex **B**

The committee

- Dr EW Roubos, *chairman*
  professor of zoology and neurophysiology; Nijmegen University
- Dr LM van Aernsbergen, *consultant*
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Annex **C**

Field strengths in the vicinity of a base station

On 5 March 1999, the Netherlands Institute of Applied Scientific Research (TNO) carried out field strength measurements at a DCS 1800 base station located on the roof of the property at Van Oldebarneveldtlaan 9 in The Hague (Ouw99). The measurements on the rooftop were made with an isotrope electric field sensor which is suitable for use in the frequency range 0.5 to 6 GHz. In an office space underneath the antenna installation and at two places on the street, measurements were made with a spectrum analyser, with which measurements can be made within a pre-selected frequency range. For these measurements the measured bandwidth was 120 kHz and was measured in frequency intervals of 31.25 - 37.5 kHz.

The broad band measurements on the rooftop were made at a height of 1.90 m at various distances from the antenna, the underside of which was located about 3 m above the roof surface. The field strengths measured at between 1 and 3 m in front of the antenna varied between 0.4 and 1 V/m.

The measurements in the office space and on the street were not only carried out in the frequency range around 1800 MHz, but also, for comparative purposes, in the range around 900 MHz (the second GSM frequency band) and in the FM band between 80 and 110 MHz. The field strengths in the frequency ranges measured varied greatly. The report gives numerical values for the ten frequency bands in which the highest field strengths were found. Using the summation formulas as stated in HCN97, a calculation of what percentage of the exposure limit corresponds to the total field strength was made for each of the frequency ranges separately and for the three ranges together. The summation formulas give the percentage of the basic restriction, in this case the SAR (annex D provides a more extensive explanation). For comparative purposes, the percentages of the limit for the electric field strengths are calculated. The results of these calculations are given in Table 5.

This example reveals that the exposure caused by the DCS 1800 base station, that caused by the separate sources in both other frequency ranges and that caused by all three sources combined, falls far below the limit. It can be observed that the exposure on the street at a distance of 75 m from the building is greater than the exposure in the office space directly underneath the antennas. It is also apparent that at the three locations where measurements were made the contributions of the GSM 900 and DCS 1800 is larger than that of the FM band. However, it should be noted that the FM band is just one of the many radiofrequency bands which contribute to the total exposure. In urban areas in Finland, the contribution of GSM 900 and DCS 1800 to the total exposure is 61% and 13% resp., which is more than the combined contribution of radio and television transmitters. In non-urban areas the contributions are comparable, the percentages being 39% and 40% resp. (personal communication from M. Hietanen, November 1999).

Table 5 Calculation of the total exposure in the case of exposure to more than one frequency.

	percentage of the Health Council SAR limit for the general public			
	FM	900 MHz	1800 MHz	total
office	1.12×10^{-8}	1.11×10^{-5}	1.50×10^{-4}	1.62×10^{-4}
street, 75 m	8.43×10^{-7}	1.71×10^{-6}	4.74×10^{-4}	4.76×10^{-4}
street, 360 m	1.31×10^{-6}	1.11×10^{-5}	2.22×10^{-5}	3.45×10^{-5}
	percentage of the Health Council electric field limit for the general public			
office	0.03	0.08	0.19	0.29
street, 75 m	0.02	0.04	0.26	0.31
street, 360 m	0.03	0.09	0.08	0.2

Annex **D**

Summating field strengths of different frequencies

The fact that problems are sometimes experienced in calculating the total exposure level for simultaneous exposure to different frequencies in frequency ranges above 100 kHz is attributable to the fact that the Health Council and the ICNIRP apply the limits for basic restrictions and those for reference levels to a certain extent without distinction. What is ultimately involved is a checking against the basic restrictions.

In the frequency range concerned, a maximal SAR for frequencies up to 10 GHz and a maximum power density of between 10 and 300 GHz are used as a basis. Maximums for the strength of the undisturbed electric and magnetic fields are derived from these basic restrictions. In contrast to the SAR, the latter values are relatively simple to measure. The mathematical relationship between the SAR and the field strength is quadratic:

$$SAR = \frac{s}{r} E^2$$

(σ = electrical conductivity of the tissue; ρ = tissue density; E = effective electric field strength).

The relationship between the power density *S* and the field strength is also quadratic:

$$S = E^2 / 377$$

Because of these quadratic relationships, it is not possible to summate absolute field strengths. Only relative values can be added up. As the value ultimately involved here is the basic restriction, in this case the SAR and power density, the relative field strengths must first be squared before they can be added. The result is a summation of relative SARs and power densities. Due to the squaring, the total will always be lower than when the relative field strengths are added up. This can give the impression of a contradiction. The important point is, that not the field strengths but only the SARs and power densities can be summated. The procedure of extracting the root of the summated squared field strengths, as proposed e.g. in the Swiss legislation (Sch99), is therefore incorrect (as one does not check against the basic restriction, but rather, calculates back again to the reference level). This yields too high a value for the relative total exposure, but that fact is ultimately immaterial with regard to determining whether the total exposure exceeds the limit, as both the linear and quadratic summations coincide at 1.

In this light, it would be more correct, when examining to what degree the exposure remains under the limit for a certain frequency, not to express this as a relative field strength but as a relative SAR or power density. When, for example, at 900 MHz with a limit of 49 V/m, the measured field strength is 2 V/m, it can be stated that the measured value is 4.1% of the limit with respect to the field strength, but that the exposure is only 0.2% of the limit with respect to the SAR. On the other hand, where the limit is exceeded, the percentage by which it is exceeded is higher for the SAR than for the field strength (for example: if the field strength exceeds the limit by a factor of 2 – i.e. 200% – this is equivalent to the SAR exceeding the limit by a factor of 4 – i.e. 400%).