Report to the AFSSE on mobile telephony and health

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Table of Contents

1 INTRODUCTION

In accordance with the mission that was conferred upon it by law and the public action plan presented to the National Health Safety Committee on 17 December 2003 concerning mobile telephony, the French Agency for Environmental Health Safety (AFSSE), must periodically publish a document updating scientific knowledge, in the specific field of high frequency non-ionizing radiation (i.e. radiofrequencies) used by mobile telephony systems. Since the committee of experts specializing in physical agents, new technologies and major developments had not yet been installed in its functions, the AFSSE created an ad hoc expert group, whose mission is defined by the mission letter of the Director General of the AFSSE, attached as an appendix to this report. This mission is to analyse all scientific publications and official reports that have appeared since the preparation and publication of the preceding expert report (in April 2003), so that the Agency can:

- write a new opinion on the plausibility of a health hazard from non-ionizing radiation produced by mobile phones, based on the current state of our knowledge,
- evaluate the progress made to date by international programmes in this field,
- identify fields where more research is required,
- make recommendations on the future scope of scientific research in this field.

Moreover, the AFSSE has asked this same group to issue a duly substantiated opinion on the study conducted by the Netherlands Organization for Applied Scientific Research (known as the TNO study) on the potential health effects of mobile phone base stations, with respect to the UMTS network in particular. This request is founded on a mandate letter dated 3 February 2004 issued by the Director General of health and the Director of economic studies and environmental evaluation (see the copy in the appendix).

The present expert report takes its place in a national and international context characterized by an abundance of research efforts and strong public demand, especially as regards mobile phone base stations. This report sums up the scientific work that has appeared since March 2003 (which was not taken into account in the preceding report), and concerns all research work on the biological and health effects of non-ionizing radiation used in mobile technology and in other new modes of radio communication (excluding radio and television broadcasting). This research refers to epidemiology, human experimental studies, *in vitro* and *in vivo* studies and animal experimentation. A specific section is devoted to current technological advances in the area of networks and dosimetry. The first section summarizes the various official reports that have appeared on these topics throughout the world, as well as the main themes of the presentations given at the scientific symposia and conferences that have been held since March 2003.

2 WORKING PRACTICES OF THE EXPERT GROUP

In order to be considered for inclusion in this report, the scientific research in question must have appeared in written form in an international journal, after receiving a favourable peer review, even though not all of these journals are of equal quality. Bibliographic research was carried out by (i) consultation of the bibliography of international reports on the topic, and (ii) systematic consultation of the Bioelectromagnetics journal from April 2003 to October 2004; (iii) consultation of the bibliographic databases customarily used by the scientific community (list A), with the assistance of key words (list B), for the years 2003 and 2004. The fact that the key words are not cross indexed increases the list of references (i.e., it avoids the exclusion of references by overly narrow selection criteria). The references have been compared with those of the prior report for the AFSSE in order to eliminate repetitions. Significant research reports that have been made public have also been analyzed. Announcements made during conferences and symposia, without subsequent publication and for which only an abstract is available, have not been taken into account.

Each article was examined on the basis of quality criteria commensurate with the field of expertise. In the field of epidemiology, for instance, quality criteria are based on the representativeness of the subjects studied, bias control, the quality of data collection, the choice of exposure indicators and the consideration of confounding factors, the quality of statistical analysis and the power of the study, which depends among other things on the number of subjects studied; in biology, these criteria concern dosimetry (the quality of the exposure system, measurement and calculation of the SAR), the design of the experiment, the statistical processing of the data and the relevance of the biological models studied).

The group met on 2 July, 4 October, 10 November and 14 December in 2004, and on 24 January in 2005; the first two meetings provided an opportunity to discuss and identify the general objectives of the evaluation and the practical aspects of its operation. Each expert was assigned the task of analysing the publications that had appeared in his or her field of expertise (certain fields were entrusted to two or three experts who worked in consultation with each other). The texts drawn up by each expert were submitted for approval to the group during several editorial meetings. The conclusions and recommendations were drawn up collectively by the group. The conclusions were based on the weight of evidence as defined by Repacholi within the World Health Organization’s framework (i.e. the scientific quality of the research, reproducibility, the consistency of the studies amongst themselves and biological plausibility (Repacholi, WHO)).

When an expert deemed it necessary to consult an outside person known for his or her field of competency, it was solely up to the expert to decide whether or not the information and opinion of the outside person were taken into account. This information is not specifically reviewed in the report.

List A: Databases consulted

NCBI (Pubmed)
Medline (Winspirs)
INIS
Psychinfo
Serfile
Sciencedirect
Nioshtic
Embase
Toxline
Femu

List B: Key words

Mobile phone	2.45GHz
*phone	GSM
microwaves	CDMA
UMTS	TDMA
WI-FI	FDMA
Bluetooth	Analogic
Radiofrequency	EMF
	RF

3 Reports and conferences

3.1 Reports

A “report on reports”, covering the same reports as those described below has just been published by the NRPB. It can be usefully consulted on the web site of the NRPB.[1]

3.1.1 The Netherlands

The Netherlands health council publishes an annual update on the health effects of electromagnetic fields (www.gr.nl). In the 2004 version (reprinted here beginning on page 63), the topics treated concern mobile phone RF fields and very-low-frequency magnetic fields from the transmission of electricity. The report provides research recommendations (including the creation of a national expertise centre for the coordination of research efforts), as well as comments on the use of mobile phones in enclosed spaces and on hypersensitivity to electricity.

This committee had previously affirmed that when the precautionary principle is invoked, exposure levels should not necessarily be decreased, but that research efforts should be concurrently strengthened. This position was misinterpreted by some readers, and the 2004 report clarifies the matter by explaining that precautionary measures do not necessarily entail a reduction in exposure limits, but rather the resolution of scientific uncertainties through additional research.

3.1.2 NRPB[2]

In 2003, the NRPB’s AGNIR[3] advisory committee on non-ionizing fields published a report on the health effects of exposure to RF fields.[4] (www.nrpb.org/publications). A year later, after wide consultation on an international scale, the NRPB published a major report on the scientific basis for exposure limits between 0 and 300 GHz.[5] In view of the substantial authority of this agency, which extends beyond the perimeter of Great Britain, it is undisputable that this document, which concludes with some recommendations for research and exposure limits, is an indispensable reference.

In January 2005, an opinion of NRPB was added to those of the two preceding reports.[6] The authors do not conduct an exhaustive review of the new data, but reach some conclusions on the state of knowledge and make several research and risk management recommendations. The report mainly concerns mobile telephony and the TETRA system.

One of the essential conclusions is that “the NRPB believes that the main conclusions of the Stewart Report in 2000 are still valid today and that a precautionary approach to mobile phone technologies must continue to be maintained.”

Other passages from this report are cited below.

Another recent report of the NRPB concerns the exposure of the public to the radio waves emitted by the antennas of micro- and pico-cells.[7]

[1] http://www.nrpb.org/publications/w_series_reports/2005/nrpb_w65.htm
[2] National Radiological Protection Board
[3] Advisory Group on Non-Ionizing Radiation
[4] Health Effects from Radio frequency Electromagnetic Fields: Report of an independent advisory group on non-ionising radiation Documents of the NRPB. Volume 14, No. 2
[5] 2004 Review of the scientific evidence for limiting exposure to electromagnetic fields (0-300 GHz). Documents of the NRPB. Volume 15, No. 3 (2004)
[6] Mobile Phones and Health (2004) Report by the Board of NRPB. Documents of the NRPB Volume 15 No.5 2004
[7] http://www.nrpb.org/publications/w_series_reports/2004/nrpb_w62.htm

3.1.3 SSI: Swedish Radiation Protection Authority

The Swedish SSI authority[8] publishes a year-end annual report prepared by an international expert group that takes stock of new scientific advances relating to "the health effects of electromagnetic fields".

The reports, written in English, are available on the SSI's website: (www.ssi.se). The report dated 2004 was published in December. Among other things, it contains overviews of the following topics: symptoms, cognitive functions and neurophysiology, EEGs and sleep, memory and research on children. The results of completed European programmes are mentioned (Perform-B, Cemfec, Reflex), as well as the progress of the Interphone programme.

3.2 Conferences

3.2.1 Maui, USA – BEMS – June 2003 (www.bioelectromagnetics.org/)

The Annual conference of the Bioelectromagnetic Society (BEMS) took place in Maui from 23 to 27 June 2003, preceded, on 22 June, by an open symposium of the "International Committee on Electromagnetic Safety (ICES)" tied to the IEEE. During the ICES symposium, a number of preliminary documents were presented on various topics related to the health effects of radiofrequencies. They were published in a special issue of Bioelectromagnetics. The manuscripts are available on the ICES website (http://grouper.ieee.org/groups/scc28/sc4/).

More than 350 participants attended the Maui conference (compared with 390 in Quebec in 2002), but few Europeans made the trip. On the other hand, numerous manufacturers (Motorola, etc.) and military participants (e.g. the Brooks, Texas joint research lab) were present.

In vivo studies, in the field of cancer in particular, which is the main health concern related to the use of mobile phones, have resulted in an accumulation of negative results in favour of the absence of risk.

On the other hand, one of the topics classified as "urgent" by the WHO – *in vivo* studies on the haematoencephalic barrier – was not dealt with in any of the presentations. It is also noteworthy that although an overview of the studies conducted on the topic of sensitivity in children was presented via a poster, no additional elements of a solution were provided during this conference, to the point that in his presentation of the WHO's research programme, M. H. Repacholi referred only to the Stewart report dating from 2000.

In vitro studies seem to be oriented towards the search for biomarkers for exposure to RF radiation via the techniques of genomics and proteomics. On the other hand, the "significant" genotoxic effects reported during the REFLEX session left scientists sceptical and the contested quality of the biological tests must not obscure the fact that one of the hypotheses that remains to be tested is that of intermittent exposure.

Although on the whole, the large majority of the results presented show no harmful health effects from exposure to radiofrequencies within a "reasonable" SAR range, it is noteworthy that this conference contributed little new scientific information (i.e. there was a significant scarcity of new results while awaiting data from the major studies currently underway). On the other hand, more politically- or strategically-oriented information was supplied on the WHO's approach to the question of epidemiological studies on base stations, now extended to all RF sources. The WHO research programme, which must be taken into account by future projects, was also discussed.

[8] Statens strålskyddsinstitut

3.2.2 Reisensburg, Germany – COST 281/FGF – The haematoencephalic barrier – November 2003

The theme of this workshop was: "Can the haematoencephalic barrier be influenced by RF fields?"

The presentations given at this workshop are available on the FGF website[9]. The main participants in research on the effects of RF radiation on the haematoencephalic barrier met for three days to present their results and points of view. They came to the conclusion that there are no *in vitro* results showing the effect of RF fields on haematoencephalic barrier models, and that on animal models, only two teams in France and Sweden have shown some permeability effects. These, however, have not yet been replicated.

3.2.3 Guilin, China – WHO – Third annual seminar on electromagnetic fields – October 2003

During this third annual conference organized by the WHO in China, recent Chinese research was presented, accompanied by lively discussion on the establishment of exposure limit values in China. The numerous positive results obtained at the national level in China are not currently "counterbalanced" by the body of largely negative scientific data obtained at the international level.

3.2.4 Budapest, Hungary – EBEA, COST 281 – Mobile telephony and the brain, November 2003

The biennial conference of the EBEA (European bioelectromagnetic association) was held in Budapest from 12 to 15 November 2003, followed on 15 and 16 November by an open COST 281 symposium on the theme of "Mobile telecommunications and the brain", during which an overview of the Reisensburg symposium on the haematoencephalic barrier (November 2003) was presented.

It was attended by approximately 250 participants, the majority of whom were Europeans who for the most part did not attend the 2003 BEMS conference in Hawaii. The COST 281 symposium was attended by approximately 100 persons.

A number of new findings were presented at these conferences held in Budapest.

The predominance of European research in this field was confirmed. The launch of the EMF-Net and EIS programmes is evidence of Europe's pre-eminent position. The accent is now on the formatting of recent or soon-to-be announced results and on the dissemination of risk information.

Studies pertaining to a potential increase in the sensitivity of children constitute a priority, which is, however, difficult to implement. Efforts are therefore being continued via both human and animal studies. The Istanbul WHO conference in June 2004 should provide an opportunity to take stock of the situation.

Recent studies bearing on subjective symptoms have been conducted primarily in the "base station" configuration (with a need for personal dosimeters): this is research conducted in response to public pressure, even though the relevant exposure levels are negligible.

The most hotly debated topics are currently the haematoencephalic barrier (HEB) and heat shock proteins (HSP). Numerous studies have been conducted, but these topics are still controversial even though the results are negative for the most part. Numerous replication or conformation studies are underway or planned on these topics.

9 www.fgf.de/english/fup/meeting/thema/reisensburg_rapport_franke_engl.pdf

3.2.5 Immenstaad, Germany - COST 281/FGF workshop on sleep - December 2003

During this workshop organized by COST 281 and the FGF, results were presented on sleep and certain cognitive functions. This data is discussed later in this report. It is noteworthy that the exposure and recording characteristics for sleep parameters are not harmonized among laboratories and that replications have often been negative within the same laboratory. The Perform C programme, currently underway in Stockholm, should help to clarify matters as regards this type of human study.

3.2.6 Bangkok, Thailand – WHO – January 2004

More than 140 researchers and representatives of Asian governments from 24 countries of the Asia-Pacific region attended the "EMF Conference on Electromagnetic Fields, Research, Health Effects and Standards Harmonization" in Bangkok, Thailand, in January 2004. Research programmes were identified in three countries: China, South Korea and Japan.

3.2.7 Helsinki, Finland – COST 281/FGF – Heat shock proteins – April 2004

A COST 281/FGF workshop was organized in Helsinki to consider recent research on heat shock proteins (HSP). No new results were presented and D. de Pomerai admitted that his earlier data on roundworms (nematodes) should be disregarded since the replications performed since the publication of the data in *Nature* have proved to be negative.

3.2.8 Seville, Spain – ICNIRP/WHO/URSI and IRPA – May 2004

For the first time, the ICNIRP symposium was organized in cooperation with the WHO and the URSI[10]. This conference offered 250 participants the opportunity to discover a very complete panorama of results from research over the entire frequency range of non-ionizing fields pertaining to the environment and therapeutic applications. This symposium was followed by the IRPA conference[11] in Madrid during which numerous sessions on non-ionizing fields were organized.

3.2.9 Istanbul, Turkey – WHO – The exposure of children – June 2004

The objectives of this conference were:

- to integrate the topic of the "health effects of magnetic fields" into the precautionary approach initiated by the European Union and the World Health Organization as regards the environmental exposure of children

- to develop a research programme.

In his introductory speech, M. H. Repacholi, director of the WHO's EMF programme recalled the history of the documents relating to the hypothesis that children are more sensitive to electromagnetic fields than adults. In the radiofrequencies range, the first document suggesting such a hypothesis was the "Stewart" report which advocated a precautionary approach since (i) the brains of children likely to use mobile phones are still under development, and since (ii) it is probable that the cerebral tissue of children is more sensitive to the absorption of RF waves than that of adults (since their dielectric properties differ). More recently, a report of the Dutch Ministry of Health concluded that the precautionary principle could not be invoked inasmuch as it was improbable to observe major modifications in the sensitivity of the brain to electromagnetic waves after the age of two years. However, it is indisputable that very little experimental

10 Union Radio-Scientifique Internationale (URSI – International Union of Radio Science)
11 International Radiation Protection Association

data is available in this regard. Thus, it is not currently possible to demonstrate conclusively that children are more sensitive to radiofrequencies than adults.

As a result, it does not currently appear to be possible to provide a conclusive response to the issue of the increased sensitivity of children to exposures to low level radiofrequencies. There are still too many unknowns and too few studies relying on specific protocols to answer this question. The basic question up to now has been whether or not exposure to low-level RF energy has health effects on adult humans and animals. It is clear, however, that children are frequent users of mobile phones: in Germany, for example, 88 per cent of children aged 11 to 15 possess a mobile telephone, and 66 per cent of these have had it for more than one year.

However, in the absence of specific studies providing conclusive evidence of the increased sensitivity of children to RF exposure, the exposure recommendations of the ICNIRP will not be changed (P. Vecchia). For all that, an evaluation of the risks linked to exposure to low-level RF emissions must continue with the inclusion of this new aspect within the overall framework of the protection of children against chemical and physical agents present in the environment.

This is why, at the end of these two days of discussion, the WHO put together a proposal on research priorities and (i) advocated further exploration in children (EEG, cognitive testing, sleep), while fully complying with national ethical regulations, and (ii) recommended further experimentation, including *in utero* and/or post-natal exposure, as well as the prolonged exposure of immature animals. The development and maturation of the brain, the haematoencephalic barrier and the immune system should be studied as a priority (see the WHO's research recommendations for children in the attached appendix).

3.2.10 Washington DC, USA – BEMS – June 2004

The 26th conference of the Bioelectromagnetics Society (BEMS) was held in Washington DC in June 2004. It was attended by 360 participants.

The number of BEMS members in North America is gradually decreasing due to the absence of federal funding. The average age of these researchers has been constantly rising since new American teams are increasingly rare in this type of research.

The 2004 BEMS conference could not be considered an “exceptional vintage”. That was already the case in 2003. This situation gives rise to a number of questions on (i) the relevance of holding these conferences on an annual basis, (ii) the likely irreversible slowdown of research efforts in this field in the United States, (iii) the lack of epidemiologists and (iv) the still modest level of medical applications.

Most of the research activity being conducted in Europe concerns the electromagnetic environment and health.

3.2.11 Paris, France – ICES/COST 281 – Thermoregulation – September 2004

The objective of this international meeting was to develop some suitable techniques to predict the thermo-physiological responses of persons exposed to microwave fields depending on the specific frequencies to which they are exposed, the intensity of the fields and their characteristics. A validation of pre-existing knowledge on the thermoregulatory response as a function of the environment (work, age, clothing, etc.) was combined with a comparison with already-known human and animal data.

3.2.12 Moscow, Russia - The health effects of mobile phones - September 2004

During this new Russian conference, organized under the aegis of the WHO, several Russian research groups presented their research activities, and in spite of their current lack of resources, they were able to retain the attention of their audience due to their prior experience. Problems related to the validity of the Russian exposure limits and the proposed replication of former Soviet research on immunity, which serve as the scientific basis for these limits, were discussed in detail.

The organizing committee that directs the Russian commission on non-ionizing fields[12] published a press release[13] demanding that precautionary approaches be implemented for the use of mobile phones by children.

3.2.13 Prague, Czech Republic – WHO – Hypersensitivity – October 2004

The scientific community as a whole, under the chairmanship of the World Health Organization, took stock of the current state of knowledge on hypersensitivities due to electromagnetic fields. They observed that this problem could only be approached from the standpoint of tangible scientific proof, and that the emotional aspect of this debate must be superseded. Numerous research efforts are currently underway, especially in Switzerland, Italy, Austria, Great Britain, the Scandinavian countries and the countries of Eastern Europe. Neither France nor the United States consider this problem to be a public health imperative. Numerous pressure groups are very active, particularly in Northern Europe, with the objective of obtaining official recognition of this pathology as a new emerging environmental disease. The conclusions of this conference have not yet reached this stage, since all the symptoms described are atypical.

This is a controversial topic, since there is a high level of concern among the public, which is skilfully controlled by a number of pressure groups. Few psychiatrists have expressed an opinion, which is regrettable, since the set of symptoms described appears to be a crystallization, and therefore a manifestation of environmental or societal ill-being.

The lack of a medical definition of this hypersensitivity contributes to the fact that it is not recognized in international medical circles. Moreover, the scientific proof of a causal relationship between exposure and clinical disorders has not been clearly demonstrated.

3.2.14 Schriesheim, Germany – Cancer – November 2004

COST 281 and the FGF organized a conference on the theme “Do RF fields increase the risk of cancer?” in November 2004 in Schriesheim, Germany (transcribed on the FGF's website: www.fgf.de). The main topics were epidemiology, animal carcinogenesis studies and a review of genotoxicity studies in animals and cells.

The vast majority of genotoxicity, carcinogenesis and epidemiological studies of cancers are negative. However, in each of these areas, one can find positive studies, such as (i) *Lai and Singh* on animal genotoxicity, (ii) *Repacholi et al.* on carcinogenesis in the transgenic mouse and (iii) *Hardell et al.,* or more recently *Lönn et al.,* on cancer epidemiology.

It is regrettable that some positive studies, such as the one showing genotoxic effects in animals, are still considered a reference even though all replication research, or research closely related to the initial protocol, have failed to confirm the initial results.

12 RNCNIRP
13 www.pole.com.ru/news_en.htm#About%20Russian%20National%20Committee

Moreover, in the fields of both epidemiology and animal experimentation, the population or animal sample size is often considered to be too small to enable the detection of a low amplitude effect. However, measures limiting animal experimentation and the cost of large-scale studies must be taken into account in the design of study protocols. Multicentred studies, such as European programmes, should make such approaches possible. One can only hope that there will be some solid studies using rigorous protocols, good models and sufficient statistical power to fully satisfy requirements for the analysis of the cancer risk related to mobile phone-generated radiofrequencies.

This conference was premature insofar as the data from European programmes, particularly Perform A and Cemfec (see section 10.2), are still not available – or only partially so – and it is thus difficult to draw reliable conclusions at the present time.

In short, a renowned epidemiologist (Savitz; Epidemiology 15:651-652 (2004)) has concluded that the cancer risk attributable to radiofrequencies (from mobile telephones) has increased slightly, in particular with the study of *Lönn et al. (2004),* from “very highly improbable ” to “highly improbable”.

4 EXPOSURE

4.1 Developments in mobile telephony

4.1.1 From Radiocom 2000 to UMTS

Although the first developments in radio communications date back to the very beginning of the 20th century (with the first wireless telegraphy experiments conducted by Edouard Branly in December 1902 in Auderville), it was not until the end of the century that mobile radio communications reached the general public on a wide scale. The 1980s were thus marked by the launch of two French mobile telephony networks, Radiocom 2000 (an analogue radiotelephony system commercialized by France Telecom Mobile) and a system derived from the Scandinavian NMT system, developed by SFR.

The technological development of second generation (2G) mobile phones, of which GSM is the “flagship” system, was prepared at the end of the 1980s with the objective of promoting the emergence of a worldwide cellular radio communications system. In fact, in spite of its popularity and its widespread development, GSM, which originated in Europe, cannot claim to have a worldwide base with a universal mission (voice and data). First of all, there are competing systems (such as CDMA IS-95 in the United States and PHS in Japan), and secondly, although frequency bands have been harmonized in Europe and Asia, this is not the case in the United States, where GSM is called PCS and is assigned to other frequency bands than those used in Europe (see Table I).

System	Uplink (MHz)	Downlink (MHz)	Channel width (kHz)	Number of channels
GSM (GSM900)	890-915	935-960	200	124
E-GSM (GSM900)	880-890	925-935	200	50
DCS (GSM1800)	1710-1785	1805-1880	200	374

Table I: Frequency bands assigned to GSM in Europe and Asia

Terrestrial cellular networks have been intensively developed throughout the world at the expense of satellite mobile telecommunications networks, which represent a more limited market. A cellular network is one in which the territory covered by the network is divided into elementary cells (see Figure 1), each equipped with a base station enabling communication with mobile phones or communication devices located in the cell.

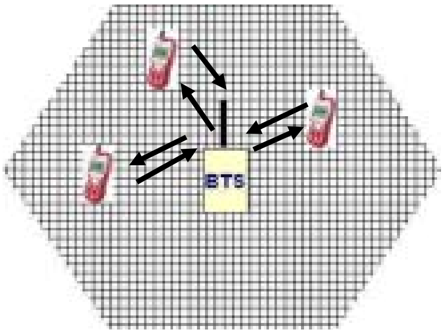

Figure 1: The radio-frequency cell principle

Contrary to the intermittent signals emitted by terminals, GSM base stations transmit continuously on at least one frequency, at a stable level and constant power (the beacon channel or “BCCH” frequency), which permits identification and field measurement by the mobile phone; when there are many calls to route, the base station uses several different frequencies. Frequencies other than the beacon channel are subject to power control and the signals transmitted over these frequencies are intermittent. These are essentially traffic channels (TCH) and the signals vary depending on the number of users and the type of transmission (GPRS voice or data) (see Figure 2).

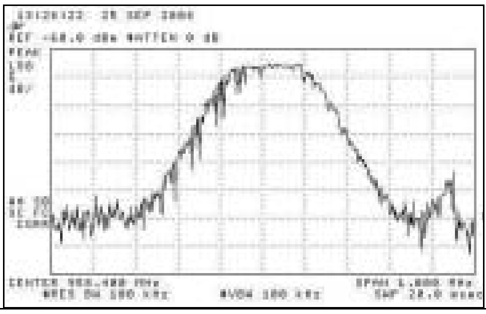

Figure 2a: Example of a continuous beacon signal spectrum emitted by a GSM base station (beacon channel)

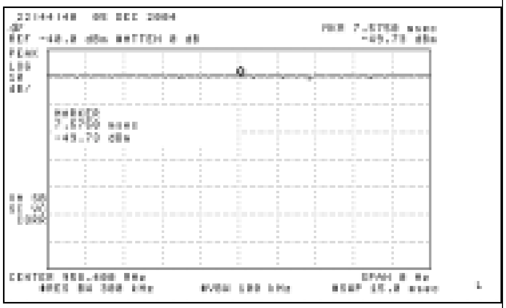

Figure 2b: Example of the time evolution of the beacon signal emitted by a base station

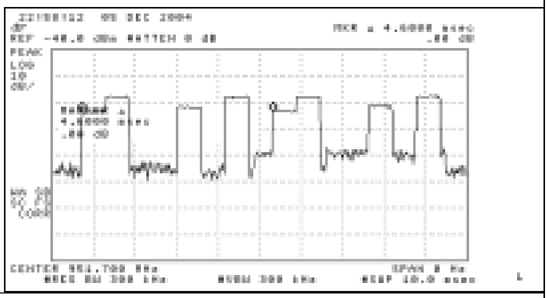

Figure 2c: Example of the time evolution of a traffic channel signal emitted by a GSM base station

GSM channels are centred at 200 kHz intervals. The relationships between the channel numbers (called "ARFCN") and the central frequencies are given by the following formulas (see Table II)

System	Channel Nos.	Uplink frequency (MHz)	Downlink frequency (MHz)
GSM 900	1 to 124	F = 890 + (0.2 x n)	F = 935 + (0.2 x n)
E-GSM	975 to 1024	F = 890 + (0.2 x (n – 1024)	F = 935 + (0.2 x (n – 1024)
GSM 1800	512 to 885	F = 1710.2 + (0.2 x (n – 512))	F = 1805.2 + (0.2 x (n – 512))

Table II: Relationship between GSM frequencies and channels

This development first went through an intermediate stage with the so-called 2.5G technology, which increased data transfer rates (GPRS, EDGE), which were initially quite low in GSM, without changing the radiofrequency infrastructures and, by and large, the radiofrequency signals exchanged.

GPRS and EDGE are distinguished by the use of several traffic time intervals intended to increase the transmission rate, with GPRS having the particularity of keeping the same initial modulation as GSM (GMSK), while EDGE implies some changes in modulation, by using the more effective 8PSK modulation, which makes it possible to significantly increase data transfer rates compared with GPRS.

This development was then continued within the International Telecommunications Union in the context of a standardization programme known as IMT-2000, which unfortunately did not lead to a single system. However, at the global level, the wide-band technology known as CDMA (Code Division Multiplex Access) was favoured.

In Europe, the predominate technology was UMTS (Universal Mobile Telecommunications System), which was defined by the “3GPP” forum and the ETSI, while in the United States, a similar but incompatible technology was chosen, through CDMA2000.

Lastly, in Japan, NTT Docomo was the first to launch a technology similar to UMTS, but not compatible with it, called FOMA. After a period of hesitation, it appears that widespread use of the FOMA system by the Japanese is well underway.

4.1.2 UMTS

UMTS is thus based on W-CDMA technology, one of the main advantages of which is the ability to attain high transfer rates while ensuring mobility. Depending on needs and the conditions of accessibility and availability of the base station, each user can be allocated transfer rates ranging from 7.5 kbps to 2 Mbps, enabling multimedia access at reasonable average data transfer rates (typically 64 or 128 kbit/s).

UMTS was also defined according to two possible operating modes, one of which is based on a distinction between the frequencies emitted by mobile phones (called “uplink” frequencies) and the frequencies emitted by base stations (known as “downlink” frequencies). This mode is known as the “FDD” mode (frequency division duplex). This mode is scheduled to be first implemented in Europe. The second mode called the “TDD” (or time division duplex mode) uses the same transmission frequency for the mobile phone and the base station, but at different times to eliminate interference.

The frequencies adopted for UMTS are summarized in Table III.

System	Uplink	Downlink
UMTS – FDD (Europe)	1920 – 1980 MHz	2110 – 2170 MHz
UMTS – TDD system	1900 –1920 and 2010 – 2025 MHz	

Table III: Frequency bands allocated to third generation technologies in Europe

4.1.3 W-CDMA

W-CDMA is a complex spectrum-spreading process by code over a frequency band of 5 MHz; a unique code is allocated to each mobile phone, which can function at the same time as others and on the same frequency without interference. A specific code is also assigned to each base station (called “Node B”), which allows the phone to distinguish between surrounding base stations, all of which function at the same central frequency.

The spread spectrum principle states that any W-CDMA signal that does not have the appropriate code in one direction or another is not decoded by the receiver, which expects a given code; this signal is then considered to be noise; secondly, any narrow-band interference falling into the reception channel is also transformed into wide-band noise for the W-CDMA receiver.

This implies rapid control, with a significant power dynamic with regard to the power emitted by both base stations and mobiles. Moreover, unlike GSM, the size of the cells can vary depending on the number of users and the data rate demand. The data rate of the coding sequence is 3.84 Mchip/s (the chip being defined as the smallest element of the coding sequence). The maximum power used for base stations is of the order of 10 to 20 W at the antenna access and up to a maximum of 125 mW for mobile phones, which is equivalent to the power of a DCS 1800 or half of a GSM 900.

The resulting signal spectrums are therefore quite different from those produced by GSM and they occupy a bandwidth of 5 MHz while GSM signals occupy only 200 kHz each (actually slightly more). On the whole, the emitted signals will not be intermittent.

Unlike GSM with BCCH, a specific frequency is not dedicated to the beacon channel, but rather a specific code, known as CPICH for Common Pilot Channel, which is continuously transmitted by the base station at a determined power level that is constant over time, although it is defined by the operator for each cell, allowing a UMTS phone to locate the cell and identify itself. On average, the power assigned to the CPICH is of the order of 10 per cent of the UMTS base station's total available power. By measuring the CPICH, one can thus estimate the maximum total power that can be transmitted by a UMTS base station.

The emission spectrum of a base station is very similar to that of a mobile phone. Figure 3: Emission spectrum of a UMTS mobile phone represents the emission spectrum of a commercial UMTS mobile phone.

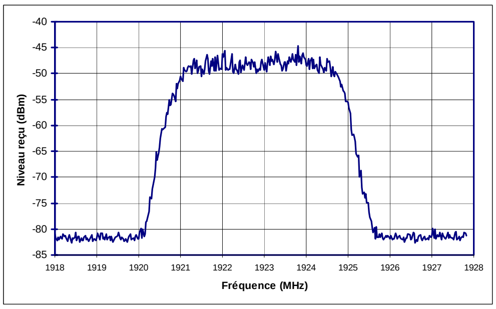

Figure 3: Emission spectrum of a UMTS mobile phone

4.2 Wireless

The exposure of the public to radiofrequency radiation is not limited to emissions from mobile telephony. In fact, beginning at 9 kHz (the first frequency allocation in the frequencies table of the radio communications regulation of the UIT-R), there are numerous “radio” applications, not only for communication purposes, but also for the dissemination of information: (FM band radio, TV, etc.). Table IV below lists the main services for each frequency band:

Frequency band	**Main types of transmission**
10 kHz – 10 MHz	An assemblage of several specific frequency bands such as “Longwave” (O.km), “Shortwave” (O.hm) and other types of radio broadcasting
10 MHz – 30 MHz	An assemblage of several frequency bands (paging, CB, radio broadcasting)
30 MHz – 87.5 MHz	PMR (private mobile radio), Band I TV (47-68 MHz), amateur radio operators, etc.
87.5 MHz – 108 MHz	FM-band radio
108 MHz – 136 MHz	Civil aviation
136 MHz – 400 MHz	PMR, ERMES, Band III TV (174-223 MHz)
400 MHz – 470 MHz	Private radio networks (PMR FM, TETRA, TETRAPOL, alphapage)
470 MHz – 862 MHz	TV (bands IV and V)
960 MHz – 1375 MHz	Radar, etc.
1375 MHz – 1710 MHz	T-DAB (1452 1492 MHz), Microwave radio systems, radiosondes and weather stations
1710 MHz – 1900 MHz	DECT: 1880-1900 MHz, etc.
1900 MHz – 2700 MHz	Bluetooth (2400 – 2483.5 MHz), radio cameras, Wi-Fi
2700 MHz – 3400 MHz	Radar, etc.
3400 MHz – 3600 MHz	Wireless local loop / WI-Max
> 3600 MHz	Satellite ground stations, Radar, etc., FH, WLL (24.5-26.5 GHz) etc.

Table IV: Frequency bands of the main transmission types

Local wireless or radio networks, still called RLANs or WLANs, have also caught the attention of the public in view of their widespread use and low cost. The goal of these radio networks is to interconnect computers without using wires and connect portable computers to the Internet or to remote servers via access points.

There are two ways of using wireless networks:

- In ad hoc mode (known as “point to point”), the network functions in a completely distributed manner (Independent Basic Service Set)

- In infrastructure mode, an access point unites wireless stations in its zone of influence and manages the radio resource (Basic Service Set)

In view of their ease of installation, these networks are used for both personal and professional purposes. Public access points or “hot-spots” are also becoming more common in train stations, airports and other public places (cafés, etc.). This allows users registered with the operator of the “hot-spot” to connect locally to the Internet.

“Wi-Fi” is the commercial name of systems that comply with American standards IEEE 802.11b or 802.11G. Another standard (802.11a) has been developed to provide additional options for local radio networks.

Table V presents the main characteristics of the IEEE 802.11x radio standards.

Standard	Frequency band (MHz)	Nominal transfer rate (Mbit/s)	Physical layer and access control
IEEE 802.11b	2400-2483.5	11	DSSS (Direct Sequence Spread Spectrum), CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance)
IEEE 802.11G	2400-2483.5	54	OFDM, CSMA/CA
IEEE 802.11a	5150 – 5350	54	OFDM (Orthogonal Frequency Division Multiplexing), CSMA/CA

Table V: Main technical specifications of commercial IEEE 802.11x radio systems

The above table refers to both modulation and access mechanisms and access protocols. DSSS is a technique for spreading the signal spectrum within a band of approximately 20 MHz for local radio networks.

OFDM is a technique for distributing the bits to be transmitted over a set of orthogonal carriers, each with a rather low bandwidth. Overall the entire set of carriers transmitted will occupy a bandwidth of approximately 20 MHz. OFDM has proven to be extremely effective for many different types of transmission (digital terrestrial television, Wi-Fi 802.11a and g, etc.), and the transmission/reception equipment is easily assembled using specialized components. Overall, since the transmitted signal is constituted of the sum of the carriers, it can once again be “seen” as a random Gaussian signal.

Table VI shows the maximum authorized power output in the 2.4 GHz band in France (ART, July 2003) and Table VII the authorized output in the 5 GHz band. These power outputs correspond to the maximum effective isotropic radiated power (EIRP) (cf. the definition of EIRP in Appendix d).

Metropolitan France		
Frequency band (MHz)	***EIRP (inside)***	***EIRP (outside)***
2400-2454	100 mW	100 mW
2454-2483.5	100 mW	10 mW
Guadeloupe, Martinique, St Pierre and Miquelon, Mayotte		
Frequency band (MHz)	***EIRP (inside)***	***EIRP (outside)***
2400-2483.5	100 mW	100 mW
Reunion Island and Guyana		
Frequency band (MHz)	***EIRP (inside)***	***EIRP (outside)***
2400-2420	100 mW	Impossible
2420-2483.5	100 mW	100 mW

Table VI: Authorized power output in the 2.4 GHz band in France (ART, July 2003)

Frequencies (MHz)	Inside	Outside
5150 – 5250	200 mW	Impossible
5250 – 5350	200 mW with DFS/TPC or equivalent or 100 mW with DFS only	Impossible
5470 – 5725	Impossible	Impossible

Table VII: Authorized power output in the 5 GHz band in France (ART, July 2003)

The electromagnetic fields produced by Wi-Fi systems that comply with the authorized levels of EIRP are generally rather weak, on average, (less than several Volts per metre at less than 50 cm) and decrease very rapidly with distance. They are moreover very dependent on the transfer rate and the traffic load of the access point.

Figure 4 shows the theoretical decrease in maximum power density with the distance in free space, for a distance greater than 20 cm with theoretical maximum traffic for an access point with an EIRP of 100 mW. In reality, these values should be significantly reduced, since they assume continuous transmission at the maximum transfer rate, which is never the case in actual practice.

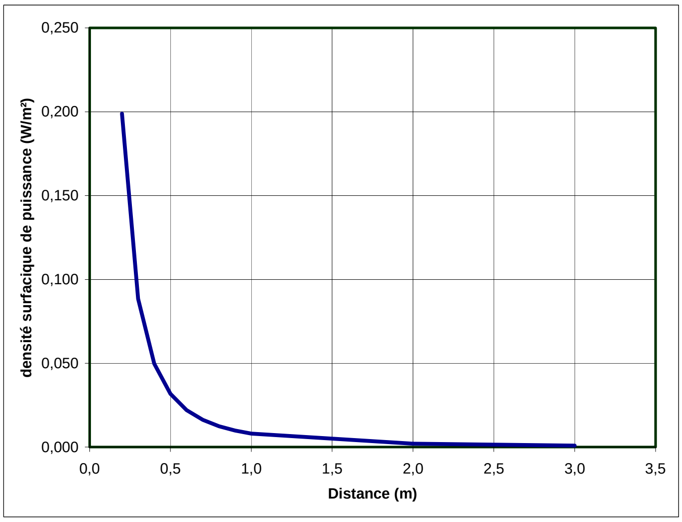

Figure 4: Theoretical decrease in the power flux density of a Wi-Fi system in free space for a maximum EIRP of 100 mW

4.3 Use and deployment

In 2004, the mobile telephony penetration rate in terms of subscriber numbers amounted to 70 per cent, or double the rate at the start of the year 2000. A recent report issued by the French Telecommunications Regulatory Authority shows an average use time for mobile phones of two hours and 10 minutes per month (three hours 34 minutes on average for package plans and 20 minutes for prepaid plans).

UMTS phones can also be operated in GSM/GPRS mode so as to be able to easily switch from one network to another, since UMTS coverage will be implemented gradually. To begin with, coverage is planned for large metropolitan areas and medium-sized cities, and it will subsequently be gradually extended.

These phones have colour screens with reasonable resolution and are equipped with mini-cameras (one or two depending on the manufacturer), extended memory for data storage (several megabytes, or even several tens of megabytes, which can be extended by the use of mini memory cards). They support several audio and video compression modes for recording and listening to music, viewing images or video, navigating the Internet and related services, and even digital TV reception (DVB-H), and they will no doubt be equipped with a GPS feature to enhance user safety through the location tracking function. They can also be used to play online games.

They can already be connected to a computer via USB or Bluetooth-type connections and could also be equipped with local radio network features of the Wi-Fi type for quicker access than UMTS, but with more limited mobility. They could prefigure “next generation 3G” systems. There are already PC or PCMCIA cards incorporating UMTS and GSM/GPRS simultaneously. These cards can be installed on portable computers or personal digital assistants (PDAs) and provide data or telephone links with people equipped with these devices.

Mobile telephone networks have been built up over time throughout the territory, with more than 60,000 radio transmission stations of all types already in place. In 2003, the total number of transmitters installed for GSM was estimated at 36,000 (Cf. Figure 5 for the deployment of the GSM network).

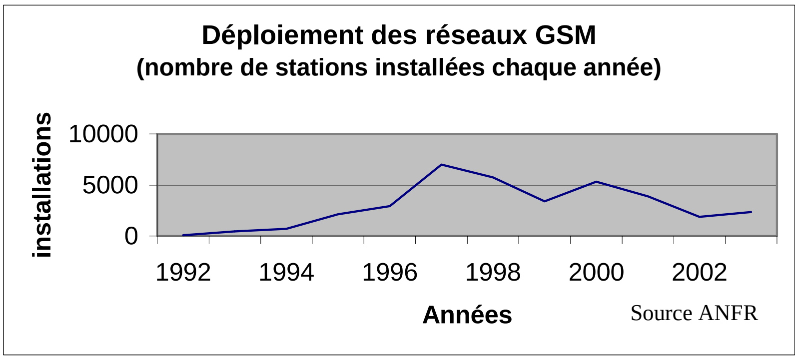

Figure 5: Deployment of GSM networks

4.4 Developments in radio communications systems

4.4.1 Context

The success of GSM, which has already been adopted by more than 43 million people in France, has created new demands in terms of both communication resources and mobility. Users are now demanding access to all modern communications media – voice, data, video – wherever they may be.

At the same time, ADSL has been deployed with lightning speed in fixed networks and already has several million subscribers in France. Both professionals and individuals have rapidly adopted this high-speed communications technology with all of its well-known advantages, particularly the ability to download vast amounts of data at ever faster speeds. As a result, users now want access to these same advantages from mobile or wireless terminals.

To respond to this demand and anticipate future needs, manufacturers are developing new communications technologies that are beginning to erase the boundaries between fixed and mobile networks. Some of these technologies are already operational, while others are still in the design stage or being studied by standardization authorities; others still will undoubtedly not survive this preliminary stage. Also, these technologies will not all be deployed simultaneously in the same locations. We should also note that increased transfer speeds do not necessarily result in increased radio power for the equipment, since this power tends, on the whole, to remain constant or even decrease.

In this context, an inventory of existing technologies and technologies proposed for standardization will give us a fairly precise idea of the developments underway. For this inventory, we had the option of classifying telecommunications systems according to user mobility, the transfer rate or the transmission range. The classification system adopted below consists in differentiating the systems according to their transmission range, which more closely reflects the use for which they are intended:

- very short-range systems for replacing wires and cables at home or in the office
- short-range systems for residential or professional local network applications
- medium- and long-range systems, mainly intended for cellular telephone use and related applications

- and, lastly, very long-range systems, comprising mainly satellite communications systems.

For this report, we will limit ourselves to instances of bi-directional transmission and we will consequently not consider broadcasting systems, such as digital terrestrial television (the DVB-T or DVB-H standard) which will be launched in France in March 2005 and which should see rapid development.

Finally, we will refer to numerous IEEE standards of the 802 type (Local & Metropolitan Area Network Standard Committee), among which we will distinguish the sub-families of standards that concern applications intended for the “general public”. These consist mainly of the following three standards:

- IEEE 802.15: standards for personal area networks (PAN), which consequently concern equipment of limited size, cost and complexity intended for use over very short distances.
- IEEE 802.15: standards for local area networks (LAN), which concern equipment of slightly greater size and complexity than equipment for PANs.
- IEEE 802.16: standards for metropolitan networks (MAN), or equipment of even greater size, complexity and power.

4.4.2 Very short-range systems

These systems have ranges of approximately 10 m with power outputs of less than 100 mW and several classes of transfer rates, ranging from 20 kbps up to 400 Mbps. The main objective is to replace the tangle of cables generally found behind electronic equipment, so that when it has to be moved, the task is not so daunting. It may be something as simple as the mouse cable (the Bluetooth mouse, for example). Other applications such as "Bluetooth earphones" are also available.

Table VIII below presents a short list of systems with transfer rates of less than 50 Mbps:

Name	**Frequency band**	**Transfer rate**	**Power**	**Range**
ZigBee (802.15.4)	868.3 MHz (one 2-MHz channel) 915 MHz (ten 2-MHz channels) 2.4 GHz (16 2-MHz channels)	20 kbps 40 kbps 250 kbps	1 mW ≤ 100 mW	10 m
Bluetooth (802.15.1)	2.4 GHz (79 1-MHz channels)	64 kbps 434 kbps 723 kbps	1 mW ≤ 100 mW	10 m
802.15.3	2.4 GHz (five 15-MHz channels)	11 Mbps 22 Mbps 33 Mbps 44 Mbps 55 Mbps	6.3 mW ≤ 100 mW	10 m

Table VIII: Systems with transfer rates of less than 50 Mbps

Along with these already existing systems, other approaches, known as Ultra Wide Band systems, are in the process of standardization. The range remains approximately 10 m but the transfer rate is much faster and can reach 400 Mbps. The (analogue or digital) "cables" that this future radio equipment could replace, typically include the peritel connector between a television set and a video recorder, a DVD player or a video projector; a printer cable or other types of cables. Transfer applications for large (audio and video) files between networked computers are also planned.

Name	Frequency band	Transfer rate	Power	Range
802.15.3a	UWB band from 3.1 GHz to 10.6 GHz	≤ 400 Mbps	See template	10 m

Future UWB systems, covering a frequency band of 7 GHz already occupied by other networks, are required to comply with extremely strict transmission requirements. An emission spectral template was standardized by the FCC in the United States in February 2002. In Europe, discussions are underway at the ETSI and CEPT level (see Figure 6).

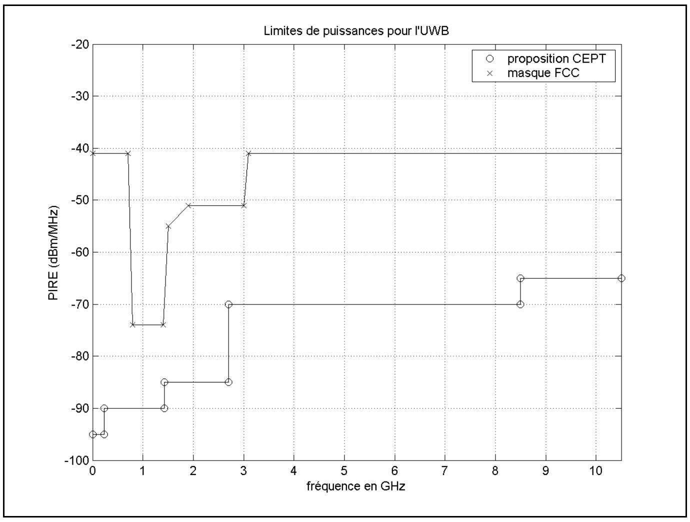

Figure 6: UWB (Ultra Wide Band) emission template in Europe (CEPT proposal) and in the United States (FCC mask authorized since February 2002) –

The template values are expressed in dBm/MHz. The value -41 dBm/MHz of the FCC mask thus corresponds to an EIRP of 79.4 nW/MHz. An emission using the entire frequency band (3.1-10.6 GHz) would consequently correspond to an EIRP of approximately 0.5 mW.

Two forms of concurrent waves are proposed for UWB transmissions, either a pulse wave form, or an OFDM wave form per sub-bands of 500 MHz (the solution of the MBOA consortium).

Finally, other solutions using much higher frequencies (in the millimetric waveband) are being studied. They have the advantage of being located in little-used bands of the spectrum (apart from a military band at about 59.3 GHz), and they make it possible to easily reuse the frequencies and to use very small antennas.

Name	Frequency band	Transfer rate	Power	Range
	from 56 GHz to 62 GHz	220 Mbps	< 1 mW	< 15 m

4.4.3 Short-range systems

The second major category concerns radio links ranging from several metres up to approximately 500 metres. The main applications are the local networking of computer equipment (PCs, printers, various servers, etc.). These systems are known under the commercial name of Wi-Fi and they combine the four standards based on the IEEE802.11 standard that appeared in 1997. This standard had two different initial versions in 1999: IEEE802.11b and IEEE802.11a. Then these two versions were partly combined in 2003 under the name IEEE802.11g. These different solutions are dealt with in section 4.2 of this report, so we will not spend any more time on them here. We would simply point out that we have not dealt with the Hiperlan II European standard, which, from the standpoint of the physical layer, is equivalent to the 802.11a solution. Lastly, the "Wi-Fi Alliance"[14] website provides a list of the public facilities where Internet access via a Wi-Fi connection is available.

4.4.4 Medium- and long-range systems

This category concerns cellular networks with ranges of several kilometres. The most important new trends currently concern the development of so-called third generation (3G) systems, such as UMTS and the competing American solution known as CDMA2000. We should also point out the appearance of new systems of the "wireless local loop" type, announced for the autumn of 2005 (e.g. WiMax: Worldwide Interoperability for Microwave Access).

The main characteristics of UMTS are presented in section 4.1 of this report. With regard to the development of this standard, we would point out that, concerning the initial frequency assignments, extension bands are planned between 2.5 GHz and 2.7 GHz. With regard to its deployment, a website[15] offers an updated list of the third generation networks deployed throughout the world as well as the number of subscribers to these networks. As of the end of September 2004, there were 9.3 million subscribers worldwide to 3G networks based on CDMA2000 1xEV-DO technology and 10.8 million subscribers to 3G networks based on UMTS FDD W-CDMA technology.

As regards UMTS, a race is underway with the competing standard, CDMA2000 1xEV-DO, to rapidly provide faster transfer rates than the 2 Mbps planned in the initial objectives. The planned development is known as HSDPA (High Speed Downlink Packet Access) and mainly concerns the downlink. It is based on a "multicodes" emission solution with a wave form in QAM16 (UMTS 3GPPR5 standard (June 2003) and is slated for a mid-2005 release, which will be followed by an R6 version). Thanks to these developments, the capacity of the downlink can thus reach 10 Mbps. The corresponding development for the uplink is called EUDCH (Enhanced Uplink for Dedicated Channels) and should be released in 2006. At the same time, the CDMA2000 1xEV-DV version of CDMA2000 1xEV-DO should make it possible to reach 5 Mbps. Figure 7 presents these developments concerning the standards for third generation mobile telephony systems.

[14] www.wi-fi.org
15 www.3gtoday.com

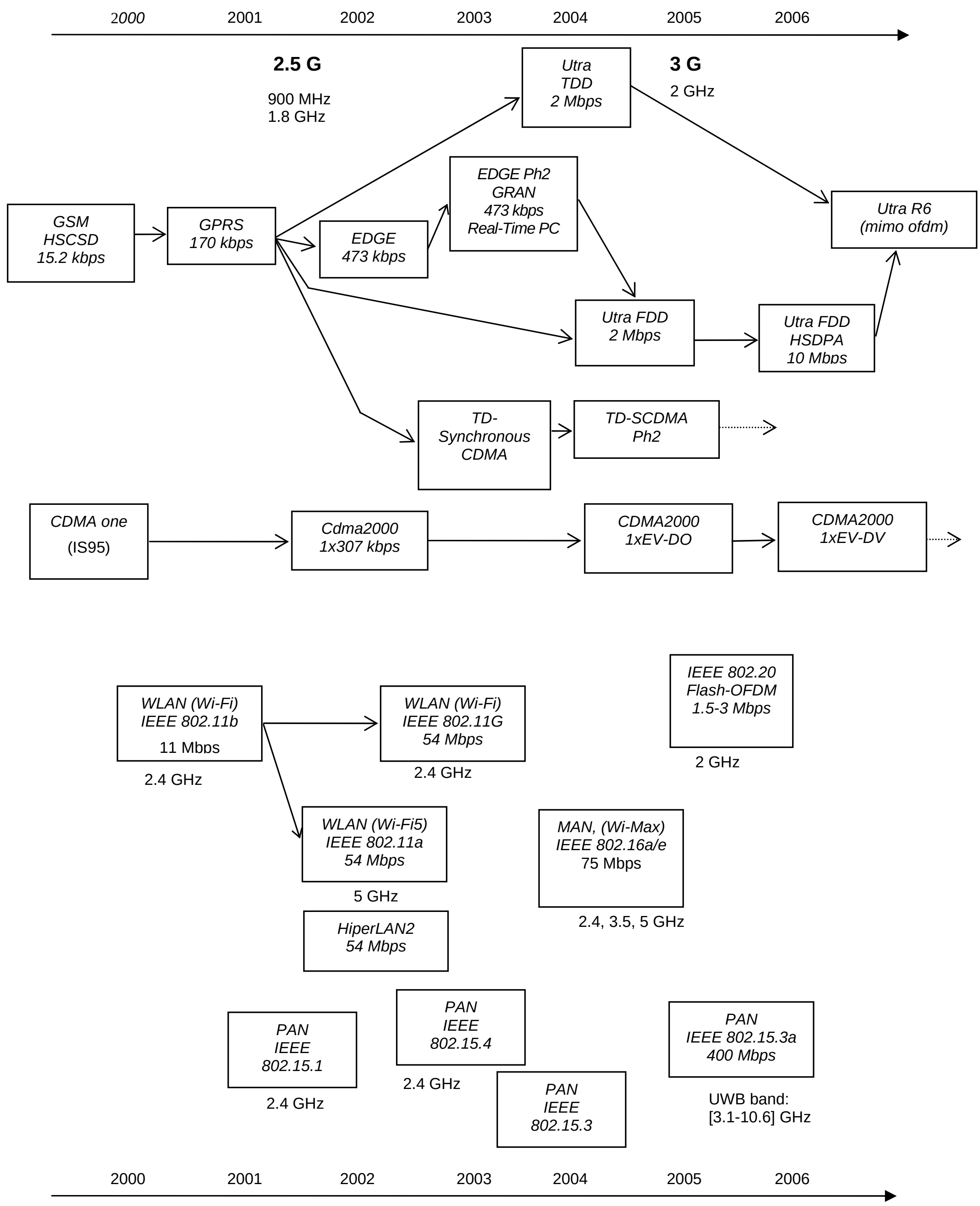

Figure 7: Development plan for third generation mobile telephony systems (including WLAN, MAN, and PAN systems)

Concurrently with the deployment of UMTS, several other solutions that will provide radio access by means of terrestrial cellular type infrastructures are in the process of development. These are mainly based on three standards: IEEE802.16a (WiMax), IEEE802.20 (Flash-OFDM/Flarion) and CDMA450 (see Table IX).

Name	Frequency band	Transfer rate	Power	Range
WiMax 802.16a	2.4 GHz 3.5 GHz 5.15 GHz 10 GHz channels of 1.2, 3.5, 14 or 28 MHz	< 75 Mbps	< 1 W (terminal*)	Cellular (<40 km, typically 5 km)
Flash-OFDM 802.20	400 MHz 3.5 GHz channels of 5, 14 or 20 MHz	< 1.5 Mbps (downlink) < 500 kbps (uplink)	< 1 W	Cellular (<20 km, typically 1 km)

Table IX: characteristics of medium- and long-range systems other than UMTS

** The WiMax terminal comes in many different forms, such as the lid of a portable PC, for example. One could also conceive of a transmission system located at a distance from the user (such as a transparent antenna attached to a window, for instance) and connected to the user by a short-range radio link.*

The initial objective of WiMax was to provide an ADSL-type wireless solution for users who do not have access to fixed wire ADSL. The initial standard did not provide for a mobile terminal. The 802.16e version of this standard now supports receiver mobility making it, to some degree, a competitor of UMTS. Launches of WiMax networks have been announced for the end of 2005. The website http://www.wimaxforum.org provides updates on the latest WiMax developments. An experimental network is already operational in the 13th *arrondissement* (district) of Paris.

4.4.5 Long-range to very long-range systems

Several telecommunication systems with low-orbit satellite-based mobile phones were developed in the 1990s. Some were put into service, such as Iridium (http://www.iridium.com/), or Globalstar (http://www.globalstar.com), but did not necessarily develop as expected. Other projects (Celestri, SkyBridge, Teledesic, etc.) were abandoned before they reached the commissioning stage. There are also some other systems based on geostationary satellites, such as the Thuraya system (http://www.thuraya.com). In most cases the user has a terminal the size of a GSM telephone, which will automatically switch from the cellular network to satellite access when the user leaves the GSM coverage area.

Several UMTS projects via geostationary satellites with higher bandwidth capabilities are currently being studied. The main problem stems from the power budget which is very unfavourable for high-bandwidth transmissions since the satellite is located at a minimum of 36,000 km from the mobile transmitter.

Name	Frequency band	Transfer rate	Power	Range
UMTS satellite	Uplink 1980-2010 MHz Downlink 2170-2200 MHz	< 2 Mbps	from 250 mW to 8 W (terminal)	Earth to geo-stationary orbit

Table X: long- to very long-range systems

Terminal EIRP must then be substantial in order to be able to meet the power budget. There are several different types of terminals, which are listed in Table XI below.

Type of terminal	Power	Antenna gain	Max EIRP
Class 1 handset Class 2 handset Class 3 handset	2W 500 mW 250 mW	0 dBi	3 dBW -3 dBW -6dBW
Portable Portable PC with semi-directional antenna	2W	2 dBi	5 dBW
Vehicle terminal With antenna on the roof	8 W	4 dBi	13 dBW
Transportable Portable PC with directional antenna	2W	14 dBi	17 dBW
Plane With exterior antenna	2W	3 dBi	6 dBW

Table XI: terminals for satellite system reception

Transmission rates remain rather low, however, ranging from 1.2 kbps to 384 kbps depending on the type of terminal. It should be noted that to obtain these values, very large antennas are needed on board the satellite (up to 25 m in diameter!). Satellite-based mobile telephony usage in France is currently insignificant.

4.4.6 Conclusions concerning the main radio access systems under development

This section has presented the main radio access systems currently under development. As indicated in the introduction, the simultaneous deployment of all these systems in the same geographic location is not a reasonable expectation. Instead, the objective should be the installation of radio networks offering the user communications solutions with substantial bandwidth and very good coverage, both inside and outside. The general tendency is to endeavour to create a denser network of radio access points with more compact antennas and fairly low power levels.

The impact of these developments on the average exposure level of the population to electromagnetic waves is difficult to analyse since several contrasting phenomena come into play.

To begin with, one can conclude that the average exposure level is increasing due to the deployment of Wi-Fi, UMTS, and so on, which are cumulative with the existing GSM system. This is essentially “downlink” exposure, however (i.e. from the network to users). Secondly, one can observe that the densification of the network results in less power being solicited from the terminals and the user is therefore less exposed during uplink transmission (i.e. from the user to the network). Lastly, the widespread availability of high-speed Internet access, with the advent of Wi-Fi (combined with fixed wire high-speed access), is modifying telephone usage, replacing it by communication via text messaging systems that use a combination of text, sound and graphics (such as "MSN Messenger"). In this situation, an increase in exposure from the deployment of a Wi-Fi network results in a decrease in mobile phone usage and therefore a decrease in uplink exposure.

4.5 Dosimetry and exposure levels

4.5.1 Mobile phone dosimetry (GSM, GPRS, EDGE, UMTS)

The Specific Absorption Rate (SAR) is used to quantify the level of exposure to the user's head from mobile phones. The SAR represents the RF power absorbed per unit of tissue mass. The European reference standard (EN 50360) stipulates that the maximum SAR value in 10g of contiguous tissue must not exceed 2W per kg. It is supplemented by standard EN 50361, which attempts to accurately define the methodology used to verify the SAR level for GSM phones. However, there are currently several studies that have resulted in a simplification of the standardized methodology (i.e. the method known as the parametric reconstruction method, for example, and the exponential extrapolation method for determining SAR). These methods result in substantial time savings during testing by reducing the number of measurement points and by ensuring that the SAR value has a highly relevant order of magnitude. This approach is very useful in a product's development stage, but is also beginning to be taken into account by the standardization authorities. There are also statistical estimation studies that make it possible to avoid invasive procedures.

The more recent GSM phones show that the SAR level does not exceed 2W/kg, but certain phones have SAR values that sometimes exceed 1.5 W/kg. The technological design problems for telephones and the limited space left for the antenna may explain these orders of magnitude.

In a similar fashion to GSM, the standardization procedures for new techniques (GPRS, EDGE, UMTS) are endeavouring to limit the specific absorption rate produced by terminals in users' heads, but depending on use patterns, physical positions different from the standard positions adopted for GSM may be considered.

In fact, it is quite plausible that a UMTS phone may be held in front of the user or placed on a table, and not held against the ear as with GSM in a rather large number of applications. However, because we are still dealing with a telephone (regardless of whether it is a UMTS or GSM phone), it would no doubt be advisable to maintain the standard positions used for the current GSM standards. Among the difficulties encountered, one of the main problems is that GSM terminals can be operated in GPRS or EDGE mode, since certain phones can transmit during several time intervals of the basic frame. The problem is to determine whether the maximum peak power is maintained in this context with several time intervals, or if for reasons related to the phones' battery autonomy and output amplifier capacity, the peak power decreases, with very different consequences in terms of maximum SAR. In fact, since it is the effective power that is used to characterize SAR, this power could double with the use of two time intervals, with a consequent doubling of the SAR.

Another potential difficulty is related to the characterization of the specific absorption rate for UMTS, in view of the low maximum power level supplied by the terminals (typically 125 mW) and the waveform of the signals emitted (wide-spectrum signals spread out over 5 MHz (see Figure 3). All these questions are being studied by the standardization authorities.

For all of these reasons, it is recommended to use an earphone or "pedestrian kit" to reduce the SAR level in the user's head. In fact, the fixed-wire "pedestrian kit" has been recognized to be effective in reducing the SAR value during mobile phone use. There is a substantial reduction of the exposure level, but in the absence of standardized measurement protocols at the international level, it is impossible to supply certified figures. Depending on the type of phone and hands-free kit, the reduction range is of the order of 10. The following figures (8a and 8b) show the reduction effect on maximum SAR provided by the use of "pedestrian kits" or "hands-free kits" on 186 GSM mobile phones (in press; source: Supélec).

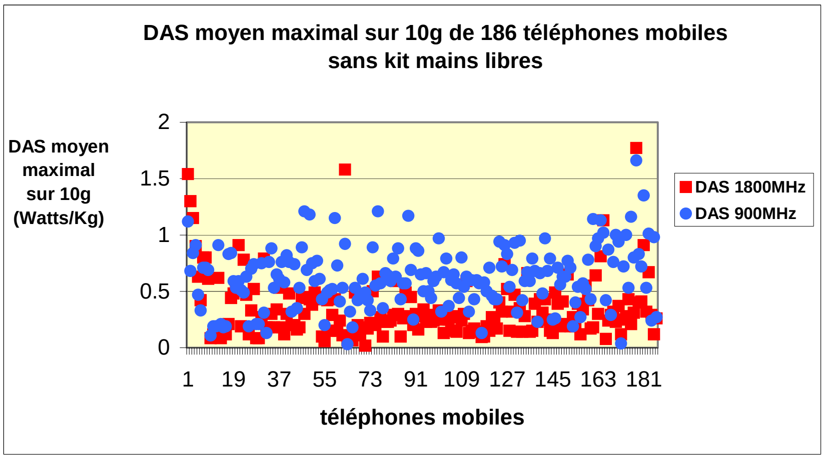

Figure 8a: SAR measurements of 186 mobile phones without a pedestrian kit

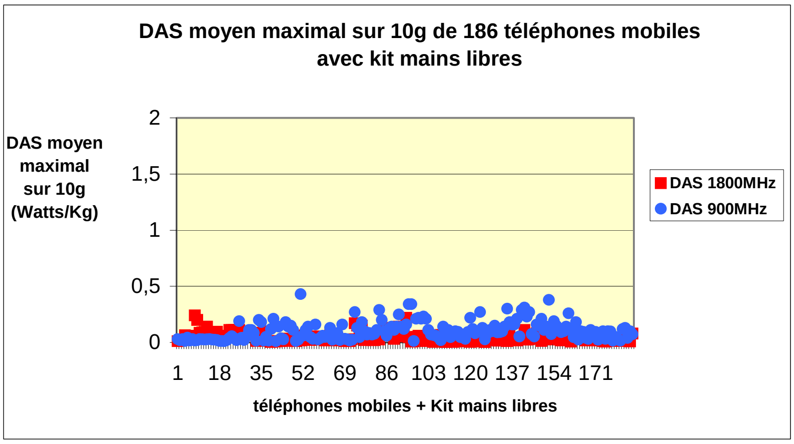

Figure 8b. SAR measurements of the same 186 mobile phones with a pedestrian kit.

The ADONIS project (**Dosimetric analysis of third generation mobile telephony systems)** of the National Telecommunications Research Network is endeavouring, among other things, to propose methodologies for characterizing the specific absorption rate for UMTS that will ensure that French contributions are taken into account during the standardization process, just as the earlier COMOBIO project had done for GSM. The project is divided into three complementary sub-projects:

ADERIS: Dosimetric analysis of head absorption of mobile phone RF radiation by children

MATIS: SAR measurement of third generation mobile phones

ISIS: Dosimetry of the relay antennas of third generation systems

4.5.2 Representative measurement of the average exposure of individuals in France

4.5.2.1 Exposure due to mobile terminals

The effective exposure of a user from a GSM mobile phone is essentially variable depending on the duration of the call and the user's body movements. In fact, in view of power adjustment mechanisms, frequency hopping between the 900 MHz and the 1800 MHz frequency bands and discontinuous transmission devices, the instantaneous power can vary by a ratio of 1 to 100 in actual practice, and theoretically by a ratio of 1 to 1000, and as a result, the instantaneous SAR can vary in the same proportions. The maximum SAR rate is rarely maintained throughout a telephone conversation, except under unusual circumstances. This can happen when the person calling is at the outer limits of the range (indicated by the low number of field indicator bars on the telephone) of any of the surrounding base stations (in an underground car park poorly covered by GSM, for example), or when the phone makes frequent intra-cellular handovers (e.g. rapid cell changes in a high-speed train).

At all events, it should be noted that GSM phones always transmit at maximum power for several seconds at the start of a call (regardless of whether the phone is transmitting or receiving a call and even before it begins to ring), and its power varies depending on surrounding conditions.

There are noteworthy differences for UMTS, because the technical principles differ from GSM. A UMTS mobile phone does not necessarily transmit at maximum power at the start of a call since the power is continuously controlled, which enables the UMTS base station to estimate the required power supplied by the phone before the start of the call. There is also rapid power control, with very rapid variations in power, up to approximately 1500 times per second.

Moreover, the sensitivity of the phone's receiver also plays a role in exposure questions, since a sensitive receiver can balance the radio link in both directions. A less sensitive phone will not pick up the network as well at the outer limits of its range, which can lead the phone to transmit at maximum power, in contrast with a more sensitive phone.

Products are currently under development that will be able to measure the instantaneous power emitted by a mobile phone in real time. They will make it possible to compute the instantaneous SAR to which users are subject, whether they are travelling along an itinerary or at a standstill. This type of device will make it possible to determine more accurately the effective exposure of mobile phone users for epidemiological studies for instance, or for the collection of exposure data.

4.5.2.2 Environmental exposure

The average individual exposure level of the population to electromagnetic fields, and particularly to radiofrequency fields, is imperfectly known to date. This lack of knowledge is primarily due to methodological problems, since measurements of this type demand very specific skills and are subject to a high degree of uncertainty.

Furthermore, harmonized measurement methodologies have only really been defined during the last few years, notably within the context of groundwork for the recommendation of the Council of the European Union of 12 July 1999 (particularly the preliminary ENV 50166-2 experimental standard published in 1995) and the mission entrusted by the European Commission to the European Committee for Electrotechnical Standardization (Cenelec) to define harmonized measurement standards. The objective of this mission was to define harmonized technical rules for the application of the Parliament's and Council's directive 1999/5 EC concerning microwave radio systems and communications terminals and the mutual recognition of their conformity. When strict measurement protocols are not respected, the differences between published results can be substantial and lead to erroneous interpretations, particularly during non-selective overall frequency measurements, thus attributing to certain visible sources frequencies that in fact originate from more remote non-visible sources.

In France, the *Agence Nationale des Fréquences* (ANFR – National Frequencies Agency) drew up a measurement protocol in 2001 for sites whose primary objective was the measurement of radiofrequency fields in the vicinity of mobile telephony base stations, but which also covered the entire installed base of fixed radiofrequency emission stations.

The measurement laboratories’ obligation to comply with this protocol stems from article 5 of Decree No. 2002-775 of 3 May 2002. This measurement protocol was amended in 2004 (V2.1) to take into account new radiotelephony technologies under development, particularly UMTS.

At the European level, the Cenelec published standard EN 50385:2002 concerning base stations – a standard developed to demonstrate the conformity of radio base stations and fixed terminal stations with the basic restrictions and reference levels for human exposure to electromagnetic fields (110Mhz-40 GHz) (OJEC of 7 December 2002/C304-17).

In the area of on-site measurement, there is also a recommendation of the Electronic Communications Committee at the European level (i.e. recommendation ECC (02)04 pertaining to the measurement of the non-ionizing electromagnetic radiation (9 kHz - 300GHz). This text, which is only a recommendation, will be applied gradually to all European countries, and the ANFR's measurement protocol refers extensively to this harmonized text. The technical control bodies accredited by the COFRAC are currently required to comply with version 2.1 of the ANFR protocol.

These on-site measurements are merely representative static measurements of exposure at the point of measurement and at a given moment in time (extrapolated as regards mobile phone base stations at maximum power). They do not take into account the mobility of the public during the course of the day and therefore are not representative of the variations in a person's exposure to different RF sources during a given period of time.

It would thus seem to be a good idea to draw on recent technological developments, and particularly the development of portable measurement devices that can produce a weighted estimate over time and in space of the exposure of persons wearing these devices for the measurement of RF electromagnetic fields.

This measurement could be determined for each of the main frequency bands (i.e. HF radio, FM radio, television, uplink and downlink GSM, uplink and downlink DCS, uplink and downlink UMTS). The objective is to have a fairly reliable measuring instrument that could compare exposure levels between the frequency bands and between various exposure situations. In principle, such a device does not guarantee a high degree of accuracy. In practice, although accuracy and sensitivity are relatively good when the device is placed on a table, when it is worn on a belt or carried in a bag, the existence of interactions between the body and the dosimeter creates isotropic problems that can distort the measurement. In spite of the lack of accuracy of this device, the data collected can be very useful for epidemiological studies since it is sufficient to establish the various exposure classes in a highly satisfactory manner. Other frequency ranges (e.g. DECT, Tetra, etc.) should be analyzed by this type of device in the future.

Various initiatives in this regard are currently underway in Europe. Their success will influence the eventual development of epidemiologically-oriented studies based on the actual exposure levels of the population rather than on more or less inaccurate or biased estimates. The small-scale distribution of such devices would facilitate the evaluation of the exposure levels of various population groups in France, particularly with regard to their location in relation to different types of transmitters or in relation to their activities. The AFSSE has issued a request for proposals to test the feasibility and utility of such devices for individual measurement techniques in subjects participating in epidemiological studies. We should point out, however, the metrological and methodological difficulties involved in this type of measurement, which is considerably more complex than fixed-site measurement, since there are no standardized protocols or reference standards. In these types of metrological studies, one must therefore pay particular attention to the representativeness of the population studied, in terms of study sites, choice of the subjects with participants corresponding to various profiles (i.e. adults, children, mobile phone users or non-users), evaluation of the mobility of the subjects during the data collection period and the duration of the data collection period. Furthermore, the actual utility of such measurements depends on the comparability of the protocols used in the various studies. Particular attention must therefore be paid to the harmonization of the protocols used by various teams with a view towards their standardization. A feasibility study for epidemiological surveys specifically based on this type of technology is currently underway at the European level coordinated by the Austrian Research Centre and involving the participation of several countries, including France (http://www.mobile-research.ethz.ch)

4.5.3 Cartoradio

To respond to questions from the public, the French government entrusted the ANFR with the mission of creating a website that would map radio transmitters. The site www.Cartoradio.fr (see Figure 9) shows the geographical distribution of radiofrequency stations of all types authorized by the ANFR. The site also provides an information sheet for each of these stations. This map is based on data supplied by public service agencies and telecommunications operators. Cartoradio also allows users to consult the results of EMF measurements in the ANFR database.

Source: ANFR

Figure 9 : Example of a "Cartoradio" web page

Updated overview of EMF radiation in France

In December 2001, the ANFR published an overview of electromagnetic radiation in France. This document was published as the result of a measurement campaign conducted primarily by its own teams. Three years after this first overview, the ANFR published a new survey; this time the synthesized data originated mainly from laboratories that took over this measurement campaign.

In 2001, the ANFR did not focus its activity on a single type of radiofrequency station, but put together a sample reflective of the existing installed base of stations of all types across all of France, with the result that this sample was representative of the the general population. Since 2001, the choice of measurement sites has been determined by the level of concern provoked by the installation of mobile phone antennas (i.e. the choice of stations is determined by demand). The 2004 results (see Figure 10 and Figure 11) therefore accentuate the impact of GSM stations on the measurements taken outside. Conversely, the impact of FM seems to be subsiding, since measurement campaigns since 2001 have moved away from high power radio broadcasting transmitters.

The graphs below distinguish between measurements made inside and those made outside, since the results of the two must be kept separate. As a result, the daily exposure of subjects can be determined according to whether they stay primarily at home or spend the majority of their time outside.

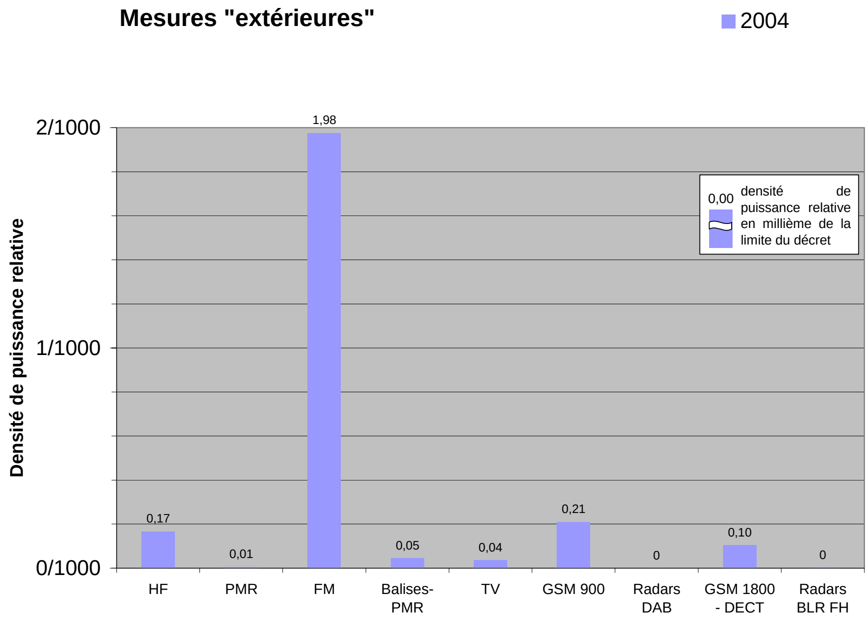

Figure 10: Outside measurements in 2004 (Source: ANFR)

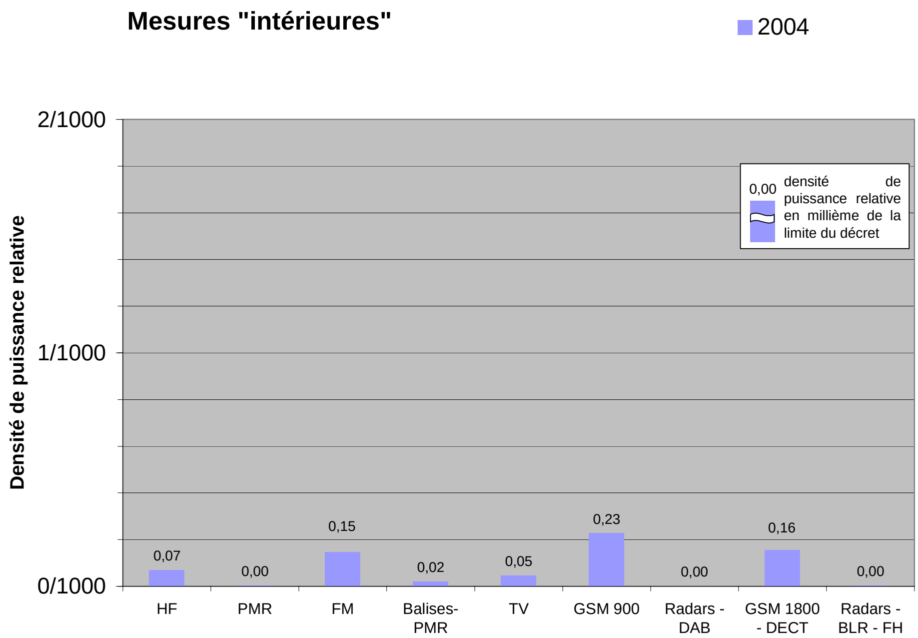

Figure 11: Inside measurements in 2004 (Source ANFR)

The various systems appear on the x-axis (the abbreviations are written out in Table XII). Their power flux density levels are related to their respective limit values on the y-axis.

HF High frequency	**FH** Faisceau hertzien (microwave beam)
PMR Private Mobile Radio	**GSM 900** Radiotelephony in the 900 MHz band
FM Frequency Modulation	**GSM 1800** Radiotelephony in the 1800 MHz band
DAB Digital Audio Broadcasting	**DECT** Wireless telephones
BLR Wireless local loop (WWL)	

Table XII: System abbreviations

Figure 10 shows that, outside, FM continues to dominate the other services, with an average exposure at 2/1000 of its limit value in terms of power flux density. Next in line, in lesser proportions, are "HF", "GSM 900" and "GSM 1800" services, with an average exposure ranging between 0.10 and 0.20/1000.

Inside (Figure 11), the main services (again FM, GSM 900 and GSM 1800) are between approximately 0.10 and 0.20/1000 of their limit value.

Even though these average exposure values are low, it should be noted that *in situ* measurement campaigns are still indispensable, since they are an effective control tool. In a document entitled "Overview of electromagnetic radiation in France – an appraisal of the situation in 2004", the ANFR announced that it is endeavouring "to verify that exposure levels remain extremely low in relation to limit values"; "it is also watching to make sure that the currently low number of sites where the levels are appreciably above average does not increase".

Along with the geopositioning of transmitters, measurement campaigns are also an effective way to communicate with the public, as evidenced by the website "www.Cartoradio.fr" (Cf. 4.5.2).

5 DATA ON BIOLOGICAL AND HEALTH EFFECTS OF MOBILE TELEPHONES

5.1 New epidemiological data

A few epidemiological studies have been published since the last AFSSE report. On the other hand, several general reviews of the question of possible relationships between radiofrequencies and cancer have been published (*Kundi, 2004 a; Elwood, 2003*).

The review by Elwood is, essentially, a review of the epidemiological studies published up to 2003: its conclusions are that the studies published to date do not suggest the existence of any risk, but Elwood also underscores the classic insufficient lapse of time, the lack of power and the difficulty of correct assessment of actual exposure of subjects to the electromagnetic fields emitted by mobile telephones. The Kundi review makes an interesting contribution in that it repositions the research in the context of carcinogenesis and provides a reminder of the specific aspects of electromagnetic fields in these frequency ranges: it underlines the difficulty of arriving at a conclusion from the studies, both long-term experimental studies on animals and epidemiological ones on humans, especially given the lack of knowledge of a mechanism that could be at the origin of a tumorogenic effect (effect of sound?). It also underlines the difficulties that will be experienced in coming years in conducting epidemiological studies, given that virtually the entire population will be using mobile telephones and that it will therefore be very difficult to find adequate unexposed populations for comparison.

In another summarising article (*Kundi, 2004b*), Kundi develops these themes again and analyses the different studies published to date on the relationship between tumours and the use of mobile telephones. Here again, he underlines the lack of physiopathological knowledge that would allow the development of credible epidemiological study scenarios. He is, in fact, highly critical of most of the studies to date, especially the case-control studies, which he ‘accuses’ of not being able to show a relationship between slow developing tumours such as neurinoma and the mobile telephone, the latency of such tumours automatically implying, in Kundi's view, a change in telephone use.

Ahlbom (*Ahlbom, 2004*) addresses the difficulty but also the necessity of taking account of frequent exposure of human tissues to radiofrequencies, requiring integration of all emission sources, which will have different characteristics depending on their frequencies. He also recalls that when studying exposure to distant sources, using the distance from the source as an indicator of exposure gives a very poor approximation of the exposure, because of the alterations to the radiofrequencies arising from the relief of terrain, obstacles (reflection phenomena, etc.). This poor assessment of exposure explains why it is not possible to conclude from the studies published that there is an excess of cancers in relation to exposure to radiofrequencies, including those emitted by mobile telephones. For Ahlbom this is also true for studies on reproduction. Where cardiovascular pathologies are concerned, published studies suggest the possibility of a risk, but the data are too rudimentary to affirm this. Similarly, Ahlbom feels that the studies conducted around radio transmission masts are not conclusive. Regarding the symptoms experienced by people close to antennas, he views the transverse method usually used as inappropriate because of the poor assessment of exposure and numerous forms of bias in information that mar collection of data in such circumstances. In conclusion, even if no study provides an element establishing the existence of a risk linked to radiofrequencies, Ahlbom is of the opinion that the converse is not demonstrated either, as too many methodological deficiencies preclude the elimination of this hypothesis. A key element for Ahlbom is the availability in the near future of individual dosimetry that will allow better evaluation of the exposure of each subject.

In a special issue of the *Scandinavian Journal of Work and Environmental Health* (*2004*), Johansen reviews all of the studies he has published to date on the relationship between health and the exposure to electromagnetic fields from extremely low frequency fields and fields created by radiofrequencies. For radiofrequency studies, this means the cohort study of mobile telephone subscribers that was the subject of comment in the previous expert report. This article presents no new results. The major questions surrounding this study, which showed no excess of tumours of the head amongst these subscribers are: (i) the cohort consisted of the subscribers, which does not necessarily mean they were the users (ii) company subscriptions were not considered because of lack of knowledge of who the individual users were, which led to a group which is very probably highly exposed not being studied and (iii) there was a lack of observation time which would have allowed study of prolonged exposure and long-term effects.

5.1.1 Tumours of the head

The first results from the Scandinavian countries participating in the ‘Interphone’ study have been published in Denmark and Sweden. These initial results relate, essentially, to the relationship between use of mobile telephones and vestibular-acoustic (VIII) neurinoma, neurinoma of the facial nerve (VII) or trigeminal (V) neurinoma, which are benign tumours localized in the inner auditory meatus, certainly one of the areas of the head most exposed to radiofrequencies emitted by telephone terminal units.

5.1.1.1 *Neurinoma of the cranial nerves*

a) H.C. Christensen et al.. (*2004*)

This study concerned 106 cases of incidence of acoustic neurinoma, paired by gender and age with 212 controls chosen at random from the Danish population. Subjects were aged between 20 and 69 years. The level of participation was 80.4 per cent for the cases and 64 per cent for the controls. Data was collected by face-to-face interview using a standardized questionnaire developed in the Interphone study and which allowed collection of data on the entire history of mobile telephone use for each subject. For each mobile telephone used, exposure data, such as the number and duration of calls, operator, type of use (hands-free, use while travelling, etc.) were collected. Conditional logistic regression models were used to calculate the odds-ratios; adjustment was made in the analyses for the educational level of the subjects.

The Danish authors of this study did not demonstrate any increase in the risk of neurinoma associated with the use of mobile telephones, regardless of the exposure indicator used. It should be noted that most of the subjects of the study used GSM technology. However, the authors did find an average size of tumours on the side of the head on which the telephone is used greater than contralateral tumours, which could concur with a role as facilitator of tumour development.

The study protocol and representativeness are good: globally, there is little difference between respondents and non-respondents which should limit the selection bias linked to a high level of non-respondents in the control group, mostly lower social classes and very probably lesser users of mobiles. Quality control allowed a check for information bias between cases and controls. The statistical analysis is adequate.

However, the time lapse for the study is inadequate where length of time of exposure is concerned, as there are very few subjects who have used the telephone for more than 10 years. In addition, the power of the analysis is greatly limited by the low number of subjects when analysis of tumours on the mobile use side (frequency, size, etc.) is attempted. Finally, as in all previous studies, the exposure indicators used only allow quantification of use of the mobile (in spite of inclusion in the analyses of the use of hands-free kits) but not actual exposure to radiofrequencies, as for that the technical characteristics of each telephone and of the networks would need to taken into account. For this very complex type of analysis, it will no doubt be necessary to wait for the global results of the Interphone project.

This study was the subject of comments by Hardell (*Hardell, 2004, a and b*), one of whose major criticisms is that the number of cases of users of analogue telephones is very low, whereas in the Danish cohort study of mobile telephone subscribers (*Johansen*[16]*, 2001*) 54 per cent of subscribers who had suffered brain tumours and tumours of the nervous system were users of analogue systems only and 13 per cent of analogue and GSM systems, which could bring into question the quality of the data collection for the Danish study. However, this criticism does not stand up, in so much as Hardell reasons for cases and compares subscribers (and not actual users) of mobile networks suffering from all types of brain tumours with cases of neurinoma amongst actual mobile telephone users. The two groups are therefore not comparable: to study the quality of information collected, it would have been more useful to compare the subscribers who were not ill (in the absence of knowledge of actual users) with the controls of the case-control study; 43.5 per cent of subscribers (99 per cent not ill) had a first subscription to analogue technology, which was the case for 30 per cent of the controls using mobile telephones (+ a proportion of the 8 per cent of those who did not know the technology of their first subscription), which returns the two

[16] Johansen C, Boice J Jr, McLaughlin J, Olsen J. Cellular telephones and cancer--a nationwide cohort study in Denmark. J Natl Cancer Inst. 2001; 93(3):203-7.

groups to a very comparable level and does not support the idea of a deficient methodology for assessment of the exposure. Moreover, the cohort study concerns a period (when the GSM was not widely used) prior to the case-control study. The second criticism concerns the analysis of the laterality of tumours and use of mobile phones: *Hardell et al.* (*letter to the editor, 2004*) think that the failure to show an increased odds-ratio for the ipsilateral side indicates that neurinoma sufferers either reduced use of the mobile or changed use side because of the deafness or tinnitus accompanying the tumour. They think that a face-to-face interview is not a good way to gather information, in so far as the data are not collected blind. Kundi, for his part, repeats, in a letter to the editor, the arguments as to the limitations of this type of study, an argument already developed in the article mentioned above (*Kundi, letter to the editor, 2004*).

In their reply, in the same journal, the authors insist on the fact that these cases had greater reason to look more deeply into their past use of mobile telephones and that the time allowed for response in the case of a postal survey is certainly more favourable to the introduction of this bias into the information than a face-to-face study in which the time of interview is the same for cases and controls.

b) Lönn S et al. (*2004*)

The same methodology was used in the Swedish study (Interphone study methodology). There are, however, some differences: pairing of controls was not done on an individual basis, but on a basis of stratification according to age; the statistical analysis used non-conditional logistic regression models, taking account of pairing variables and educational level. For analysis, the authors took as the control group all of the controls questioned for the Swedish Interphone study (including controls for the 'brain tumours' and 'parotid gland tumours' controls). The study involved 148 cases and 604 controls. The level of participation was 93 per cent for cases and 72 per cent for controls. Globally, there is no excess risk of neurinoma from using a mobile telephone. However, certain results are worthy of notice: there seems to be a slight increase in risk when duration ($OR_{\text{more than 10 years}}$ = 1.6; 0.7−3.6) and/or latency of exposure ($OR_{\text{more than 10 years}}$ = 1.9; 0.9−4.1) increase, although the increase in risk is not significant. It seems to be more the result of the use of analogue telephones (but there is a definite lack of elapsed time where GSM is concerned). Finally, the analysis of laterality of the side of use of the mobile and the side of the tumour shows a significantly increased risk for ipsilateral tumours ($OR_{\text{more than 10 years}}$ = 3.1; 1.2−8.4; based on 9 cases) whereas when use is contra-lateral there is no excess ($OR_{\text{more than 10 years}}$ =0.9; 0.2−3.2; based on only 4 cases). There is no increase in the odds-ratio with the cumulative number of hours or cumulative number of calls.

The same rigour of protocol is observed as in the Danish study, especially for the cross-referencing of sources of case declarations, or in checking of diagnosis. The study has considerable power, especially for analyses of duration of exposure, latency, type of technology used and laterality. However, power is inadequate in some analyses.

Conversely, this article gives less explanation of non-responding cases and controls, which prevents evaluation of the extent to which a possible selection bias was controlled. The question can be raised as to the impact on the results of a non-conditional analysis requiring entry of all pairing factors into the analysis. Finally, and here again as in all of the previous studies, the indicators chosen provide for study of use of the mobile telephone and not actual exposure to radiofrequencies. In particular, what is the significance of long-term use or long latency (it is impossible to separate the two analyses as those who took up the mobile phone more than 10 years ago are often also those who have been using it for more than 10 years) in relation to the fact that intensive use (in terms of cumulative hours or number of calls) is not associated with an excess risk? This type of question is difficult to study given that, at present, there are no available elements concerning possible physiopathological mechanisms.

In all, although questions of methodology remain to be answered, in the light of this study which corroborates some of Hardell's results, several elements tend in the direction of a possible impact of use of mobile telephones on the inner ear.

However, it must be emphasized that these studies remain preliminary studies, in that they are part of the Interphone study which has been scaled to group cases at the international level (13 countries) so as to be able to respond with maximum statistical power to the question of the relationship between mobile telephone use and tumours of the head. Thus, 1000 to 1100 cases of neurinoma will be included in the study, which will allow much finer analysis of the types of technology, taking account of confounding factors and analysis of modes of use. Similarly, the enormous task of analysis of the telephones used, the dose levels they emit and the areas of the anatomy exposed should, eventually, allow a better approach to knowledge of the risk.

c) Warren et al. (*2003*)

The intra-temporal portion of the facial nerve is also greatly exposed to radiofrequencies emitted by mobile telephones during communications and facial neurinomas are extremely rare. Warren has compared 18 subjects with this type of neurinoma with 51 subjects with acoustic neurinoma, 72 suffering from sinusitis and 69 suffering from dysphonia or gastro-oesophageal reflux. No excess risk in relation to the use of mobile telephones was found for tumours of the facial nerve. However, this negative result cannot be retained, mainly because of the small number of cases presented (two cases).

5.1.1.2 Brain tumours

Furthermore, Stefan Lönn (*Lönn, Stockholm 2004*) has publicly supported his thesis on the totality of the data gathered in the Interphone study. The study of the relationship between the use of mobile telephones and brain tumours is the subject of a pending article. The level of participation of cases with gliomas was 74 per cent (n=371) and that for cases with meningeomas 85 per cent (n=273). The same control group used for analysis of neurinomas was used for comparison for analysis of brain tumours. No excess risk was found (OR glioma = 0.8; 0.6−1.0 – OR meningeoma = 0.7; 0.5−0.9) regardless of the type of analysis (no relationship with duration of use, no difference if analysis takes into account use of analogue or GSM telephone, no difference between sub-types of glioma, no relationship between location of tumours and side of use, no difference between rural and urban users). As the methodology was identical to that of above study, we will not go over it again. Here again, it will be necessary to wait for the entire international study to have adequate statistical power, especially where sub-group analyses are concerned and particularly for those depending on the laterality of the tumour.

A descriptive study in the Scandinavian countries tends to indicate that the level of incidence of brain tumours, standardized by age and gender, has been very stable over the past 20 years (study period: 1968 to 1998), taking 1983 as the reference year (year of introduction of imaging systems improving diagnosis of brain tumours). In particular, this level did not increase after the appearance of mobile means of communication (wide distribution of GSM technology from the early 1990s, i.e. a time lapse of 6 to 8 years) (*Lönn, 2004; 2*).

5.1.1.3 Eye tumours

The eyes are also considered as being able to be exposed to the fields emitted by mobile telephones. A descriptive study conducted in the United States did not reveal any evidence of an increase in melanomas of the eye in recent years (*Inskip, 2003*).

However, it must be borne in mind that descriptive studies of this type lack the sensitivity to be able to detect increased incidence of a pathology, especially if the pathology is complex (different types of tumours having very different mechanisms) and if the risk sought is very low and incidence of the pathology also very low.

5.1.1.4 Tumours of the parotid gland

Another exposed area is the parotid gland (salivary gland beneath the ear at the point of the lower jaw).

d) Hardell et al. (*2004*)

Hardell applied the same methodology as in previous studies to the study of cases of tumours of the parotid gland. The cases were from Swedish cancer registers and the controls were chosen at random for the most part from a pool of controls selected for the study of brain tumours; another fraction of the control group was chosen from the Swedish population register. The study involved 267 cases (91 per cent of identified living cases) and 1053 controls. No increase in risk was observed, nor any relationship with the use of analogue technology (OR = 0.92; 0.58−1.44), nor with GSM (OR= 1.01; 0.68−1.50) nor with use of cordless telephones (OR = 0.99; 0.68−1.43). There is no exposure latency effect.

The main methodological questions raised relate to (i) the choice of controls, of which a part were from the study of brain tumours (ii) the fact that 99 cases were not included because they were too ill or deceased, and (iii) the assessment of exposure of the parotid gland: exposure of this area to radiofrequencies arises from some types of telephones (flips) and very little from others. The advantage of analysis in accordance with histological sub-types of tumours and type of technology is low, given the very low numbers in each type. It is therefore very difficult to conclude that there is definitely no relationship between use of mobile telephones and tumours of the parotid in this context.

5.1.2 Other pathologies

Johansen (*Johansen, 2004*) recalls that on the basis of the study of the potential effects of ELF 50 Hz and mobile telephones, there is no proof of danger of cardiovascular or neurodegenerative disorders. There have been no new studies on this topic since the last report.

5.1.3 Subjective effects

The survey by *Balikci et al. (2004)* is a questionnaire survey of 795 people (of which 146 non users). After statistical processing (ANOVA), reported effects are things like irritability; headache; loss of memory, diminished reflex and increased carelessness. Conversely, no significant increase is seen in dizziness, shaking in the hands, feelings of discomfort or auditory sensations. This study raises the usual problem for transverse type studies, that of control of bias in selection and information (for example, few details are given as to the type of questionnaire used; with regard to the symptoms studied, collection of information is a delicate point). In addition, the statistical analyses are not the most appropriate and make interpretation of results difficult.

This type of publication raises the question of the relevance of studies lacking proper mastery of the methodologies of epidemiological investigation.

Wilen et al. (Wilen, 2003) have repeated the Swedish and Norwegian study on symptoms experienced by mobile telephone users and, standardising on the four most used types of sets, studied the relationship between the SAR from each set and the symptoms reported by subjects. 2197 people telephoning for at least 2 minutes per day were incorporated in the study. The SAR for each set was calculated at three levels on the head (above, at and below the ear). The symptoms experienced during use, and the characteristics of the calls (number of calls and duration) were collected by means of a questionnaire. Univariate analysis of variance (ANOVA) allowed study of the relationship between symptoms and SAR. Some symptoms, such as a feeling of discomfort, reduced concentration, a feeling of heat at the level of the ear or headache seem to be associated with the SAR level. This study completed the first one. However, the fact that numerous tests were carried out increases the probability of observing statistically significant results.

5.1.4 Use of mobile telephones while driving

In addition to the numerous experimental studies (see below) which continue to study the impact of the use of mobile telephones on driving, it is worth drawing attention to the Quebec study by *Laberge-Nadeau et al. (2003)* of GSM users who are customers of the SAA insurance company in Québec. This major study attempts to control in so far as possible the bias linked to measurement of exposure to mobile telephones (before or after an accident) present in published studies. The group (recognized as an authority in the area of accident epidemiology) shows that the relative risk of accident associated with use of mobiles while driving is around 1.2−1.5 (less, therefore, than that previously calculated, but nonetheless real) once other well-known risk factors (such as speed, age and annual mileage) were taken into account. However, the relative risk increases with telephone use: it doubles when the number of calls is around 190 per month (6−7/day) for men and 115 calls/month (4/day) for women.

Pöysti et al. (pending) are to publish a Finnish study (N=834, taking account of age, gender and mileage). The questionnaire is of the self-assessment type (control, rapidity, performance, reaction time, etc.) In the light of the self-assessment, the accidents result from tactical/strategic choices made by drivers, and not from an increased risk due to mobile telephones. Reduced attention caused by the use of mobiles when driving can be compensated for by a variety of strategies, more or less effective, depending to some extent on the person. For example, lower performance on the part of older women, but they are also the group who least often use mobile phones while driving.

A New Zealand study (*Sullman & Baas, 2004)* has analysed the influence of the use of mobile telephones while driving on accident numbers. Questionnaires were distributed in service stations. The responses, in terms of frequency of accidents were declared by people (and not by insurers). The typical ‘telephone user’ profile is a young, male city dweller driving a recent and powerful car, with high annual mileage (this same profile was found by *Pöysti et al.* in the study mentioned above). Once the descriptive and demographic data have been compensated, there is no difference between users and non-users of mobile telephones. There is, however, a parallel between the typical user of the mobile while driving and the high risk category of the subject.

Several other studies show that use of the telephone while driving often correlates with risky driving: high speed, less respect for the highway code, not wearing seatbelts (*Eby, 2003)*. It is more frequent amongst men, especially young and middle-aged men (*Sullman, 2004*). The same observation is made by *Wilson et al. (2003).* In spite of legal restrictions on the use of telephones while driving, *Taylor et al. (2003)* show that more than 20 per cent of young or middle-aged male drivers telephone while driving, and that this use of the telephone is more frequent in the evening than in the morning or afternoon.

5.1.5 Conclusions on the epidemiological data

The appearance of a (Scandinavian) study showing a possible increase in risk of occurrence of vestibular-acoustic neurinoma during prolonged use of the mobile telephone reinforces the doubt expressed by two previous Scandinavian studies, in the absence to date, however, of any possible physiopathological mechanisms. The Danish study, for its part, did not find an increased risk of neurinoma but a larger average size of tumours for tumours on the side on which the mobile telephone was used. However, the not very sophisticated statistical analyses and the insufficient numbers in these studies do not allow clear conclusions to be drawn and this will, no doubt, not be possible until after publication of the data in the general Interphone study. Interphone will allow a deeper examination of the cause-effect relationship by improving assessment of the exposure of tissues likely to be concerned by the development of tumours. This international study will not, however, answer the question of a possible increased susceptibility in children. Moreover, there may still be insufficient distance in terms of latency period to assess the development of slow-developing tumours.

As the new elements provided by the Lönn thesis do not show an increase for other tumours of the head, especially of the brain, they go against results previously observed, also in Sweden, by Hardell. Once again, it remains necessary to await the findings of the Interphone study, the only one with sufficient statistical power to throw light on this question.

The use of telephones emitting at the highest SAR could, in certain subjects, cause localized symptoms, already mentioned in the previous expert report.

The inadequacy of the data on other pathologies, especially neurological, is worthy of note.

The risk of accident may be lower than that measured in the first studies, but it remains real. Use of mobile telephones forms part of a general profile of people at risk of road accident (young men making high numbers of journeys and who are careless about safety). The distraction caused by the telephone can be compensated, but only to a certain extent (for example, lower performance of older women, but they are also those who make least use of the telephone while driving).

5.2 New experimental data on humans

Several general publications appeared in the 2002−2004 period. Essentially, these reviews do not provide new or original data, but they have the advantage of summarising certain general trends.

The two reviews by *Andrea et al. (2003, a, b*) give a round up of the present state of knowledge, and especially of the uncertainties, whether relating to human or animal studies. Where humans are concerned, the possibility of effects on the cerebral tissue is noted, perhaps even in the absence of thermal action. The conclusions remain hesitant, and it is very difficult to conclude on the existence of a health risk for humans, and especially to compare investigations given the many parameters involved: frequency, orientation, modulation, power density, duration of exposure, etc. The basic question is, what in the absence of measurable thermal effects, are the non-thermal health effects? The reality of thermal action is proven and is clearly harmful, as evidenced by aversion or flight behaviour on the part of animals. It would seem that no such experiments have been carried out in humans.

The work not included in these reviews is described below.

5.2.1 Experimental studies of subjective effects

Research has continued into the subjective effects of the use of mobile telephones. Either users have complained, more or less spontaneously, of various unpleasant sensations, or they have been asked during a survey, or researchers have been actively concerned with the problem and have designed experiments. It is obvious that it is often difficult to distinguish between the three strategies for investigation and many of the studies are unsatisfactory where dosimetry is concerned.

The conclusions of a recent conference, held in Prague in October 2004 (see 3.2.14) are worthy of note, finding, to date, only atypical symptoms that are encountered in all situations of discomfort related to the environment and which mean that, at present, a true hypersensitivity to electric fields or radiofrequencies is not demonstrated.

5.2.2 Cognitive functions

Some studies on the central acoustic canals. *Bak et al.,* (*2003*) have compared the cerebral responses to sound stimuli during or in the absence of GSM telephone emission (900 or 1800 MHz) in 45 young volunteers of both sexes. No effect was observed in conduction in the acoustic nerve. However, in the absence of precise dosimetric data, it is difficult to assess these results.

The same overall approach was used by a group in Japan (*Arai et al., 2003*) where 30 minutes of exposure to a mobile telephone signal had no short-term effect on the central acoustic canals (in practice on the auditive response of the brain stem), in 15 volunteers exposed to 800 MHz, at 0.8 W, in conversation position for three minutes.

A third type of study on the central acoustic canals was based on an ‘oddball’ discrimination task (recognition of unusual numbers in a series) with simultaneous analysis of evoked cognitive potential (*Hamblin et al., 2004*). Twelve participants attended two sessions at one-week intervals, with one exposure for one hour to GSM (SAR evaluated at 0.87 W/kg), the other with sham exposure. Some modifications were observed in components connected with the target, and some increase in reaction times, but no change in precision of performance. In conclusion, there is an effect, registered electrophysiologically, but the sample was very small and caution is necessary.

Hinrichs & Heinze (2004) carried out a study to assess the effects of GSM 1800 on verbal memory. The 12 subjects were first presented with a list of words then, in a second session, had to distinguish new words from those presented the first time around. The study included a magnetoencephalographic recording of characteristic responses at 350−400 ms in the recall phase. Each subject attended two sessions, one with exposure to GSM (SAR 0.61 W/kg), the other without exposure. The authors indicate change in the analysed components, but no significant change in behaviour.

The study carried out by a Finnish group (*Krause et al., 2004*) examined a different class of cerebral responses: ‘event-related synchronization and desynchronization’. These terms describe sudden changes in electrocortical rhythms caused by a stimulus or action, either increasing or eliminating them. In 24 subjects, these phenomena were studied in the 4−6, 6−8, 8−10, and 10−12 Hz frequency bands while the subjects were carrying out an auditive memory task. With a double blind, all the subjects carried out the task either with or without exposure to a 902 MHz field (SAR of 0.88 W/kg over 1g and 0.65 W/kg over 10 g). The group did not find the results observed in the previous study.[17] They had not previously reported significant effects of radiofrequency exposure on the number of incorrect responses in the memorization task, whereas a number of errors were observed here. In other words, the reasons for variability are poorly controlled for this type of study. ORL and neurological condition was apparently only checked by questioning.

Other studies have focused on ‘spontaneous’ electrical activity used as a marker for possible alterations to brain functioning. *D’Costa et al. (2003*) observed 10 subjects in the waking state exposed at random intervals to 5 minutes of GSM pointed at the back of the head. The GSM 900 operated without an earpiece, emitting at maximum, or on stand-by, normal or open. The EEGs for periods with real or sham exposure with single blind were compared. Analysis of power spectrum distribution showed modifications in the α (8−13 Hz) and β (13−32 Hz) bands in full power mode. A second, deeper analysis revealed that,

17 Krause, C. M.; Sillanmaki, L.; Koivisto, M.; Haggqvist, A.; Saarela, C.; Revonsuo, A.; Laine, M., and Hamalainen, H. Effects of electromagnetic field emitted by cellular phones on the EEG during a memory task. Neuroreport. 2000 Mar 20; 11(4):761-4.

in seven specific frequency bands, the differences were not the same. The authors conclude that there are differences, and a GSM effect in speech mode and not in standby mode. Although the statistical study was carried out well, there is no mention of dosimetry, totally limiting the significance of these positive results, especially given the very unusual, and totally unjustified, position of the telephone.

Kramarenko and Tan (*2003*) have made telemetric recordings of the electrocortical activity in subjects exposed (or not) to a GSM-900 mobile telephone, on stand-by and in contact with the skull. After 10 to 15 minutes, the EEG shows delta-type activity (2.5 to 6.0 Hz). This also appears in children, but at even slower rates. These results are worthy of attention in that delta activity in a waking subject is not normal and replication is no doubt called for. Unfortunately, the experimental conditions were such that these results cannot be taken into consideration. Where dosimetry is concerned, the only element presented is mapping of electromagnetic fields extracted from a model for which only the name of the simulation software is known. Whether or not the human head model was also fitted with 16 electrodes is not stated. Finally, the EEG signal is itself transmitted via an RF telemetry system described very briefly. All of these elements mean that there must be serious reservations regarding these results.

Hinrikus et al. (2004) carried out a very detailed study of changes to the EEGs of 20 healthy, volunteer subjects with and without exposure to microwaves (450 MHz pulsed, modulated at 7 Hz with a fill factor of 50 per cent). A very good dosimetry study is also presented. The SAR levels are very low here: 9.5 mW/kg. The modifications are compared with those induced by visual stimulations (on-off modulation at 16 Hz). They observe modifications consistent with visual stimulations, much less stable with microwaves, especially from one subject to another, with increase or decrease of certain EEG rhythms and even variable inter-hemispherical differences. Globally, the differences are not significant and one may wonder what this study, with such weak fields, can contribute to the debate on the biological and health effects of microwaves!

Another German group (*Maier et al., 2004*) carried out a psychological auditive discrimination test on 11 volunteers (perception delay threshold between successive stimuli). Each subject participated in two test sessions with 30-minute rest periods, with and without remote exposure to the pulsed GSM field (10 W/m^2). For 9 of the 11 subjects, results were worse after actual exposure. The authors' conclusion is conventional: avoid prolonged use, especially for high-risk subjects (children, the elderly, ill people). Here again, the dosimetric data appear inadequate.

Curcio et al. (*2004*) examined the effects of radiofrequencies on cognitive performance and tympanic temperature. The subjects formed two groups, one exposed to 900 MHz before the session, the other exposed to the same signal during the data gathering session (each exposure lasting 45 minutes). The subjects participated in double blind fashion in four performance tests: one simple acoustic reaction time (RT) test, a visual research test, an arithmetical subtraction test, and an acoustic choice RT test. The tympanic temperature was also measured five times during each session. The results lead to a better score in both auditive RT tasks, accompanied by increased tympanic temperature on the exposure side. A parallel appeared between the two classes of effects such that both were only altered after 25 minutes of exposure. Dosimetry was obtained by phantom simulation (0.5 W/kg). The theoretical discussions connect this delay with that of changes to cerebral vascularization.

The Finnish authors (*Haarala et al., 2003a, Haarala et al., 2004*) replicated and extended their 2000 study on the effects of GSM 900 on cognitive functioning. In the previous study, they observed that under exposure to GSM, the RT in a simple reaction time test was shortened, as was the time for an arithmetical operation. Progress consisted in introducing multicentric tests into the new study and a double blind method. Sixty-four subjects (of whom 32 were men) were twice subjected to an array of nine cognitive tests in two independent and separate laboratories, once with a GSM switched on, once with it off. Reaction times and precision were assessed. There was no significant difference in performance, neither between laboratories nor between the sexes. The former results were not, therefore, reproduced. The authors conclude that the radiofrequencies have no effect on performance. If there are any effects, they are too slight to be detected with the means used. Here again, there appears to be a lack of certain dosimetry measurements or calculations.

Lee et al. (2003) analysed 78 randomly chosen students exposed to mobiles in the normal position of use on the head and subjected to attention tests. They observed a dose-dependent improvement in performance.

A British study (*Smythe and Costall, 2003*) of a group of 33 men and 29 women addresses the effects of the GSM-1800 on a short-term and longer term (1 week) memory test. Dosimetry is not presented, but the SAR level would have been 0.79 W/kg (manufacturer's data). It seems that exposure to the GSM had functional consequences (facilitating performance) but only for the men; the women showed no significant change.

Swiss researchers, in Zurich, have published two articles addressing both dosimetry (with a great deal of care) and actual effects on sleep (*Huber et al.,* 2003; *Kuster et al., 2004*). The detailed dosimetry study (with simulations and head model measurements) was carried out to check the actual SARs reached in the brain during experiments. The SAR levels attained went from 0.1 to 1.5 W/kg depending on the exposure system and area of the brain. The authors recall that in two previous studies, they had shown radiofrequency effects similar to those of mobiles (900 MHz; maximum SAR 1 W/kg) on the brain of healthy subjects exposed either intermittently during their sleep (8 hours) or during the waking period (30 minutes) preceding 3 hours of daytime sleep. This study enlarges on the previous two, with dosimetry being as sophisticated as possible, taking account of the variability and uncertainties and based on phantom studies involving 24 equivalent tissue parameters. Compared to control conditions, (exposure to an inactive sham) the spectral power of the EEG during non-REM sleep showed an increase in the 9−14 Hz band for both experiments and without topographical differences, so that, even in the case of unilateral exposure, modifications to the EEG were bilateral, suggesting a possible effect at the sub-cortical (thalamic) levels. In the authors' minds, these EEG results are merely preliminaries and are to be pursued. Moreover, *Kuster et al.* express their concern for optimum determination of conditions of radiofrequency exposure, convinced that many results announced are contradictory because of inaccurate or incomplete measurement. The discussion addresses the best way of evaluating the signal, field distribution and power and the best devices for dosimetry.

5.2.3 Physiological functions

In the area of temperature regulation, and following on from their previous work published in 2001[18], *Adair et al. (2003)* have conducted a new type of thermophysiological study (production and loss of heat) in six volunteers subjected to dorsal exposure (whole body) with continuous 100 MHz radiofrequency waves, at three power densities, tested at three different ambient temperature levels and a sham exposure (30 minutes control period, 45 minutes radiofrequency or sham, then 10 minutes control). No change in the metabolic production of heat was recorded. Even skin temperature was not affected (except for skin at the ankle) (3−4 ℃). Little cha nge is observed in the oesophageal temperature. In another publication *(Foster and Adair, 2003),* these authors have studied the effect of exposure of a thermoregulatory model to different frequencies (100, 450, 2450 MHz) in a variety of experimental conditions, at energies comparable to real conditions. Although all of these studies do not concern GSM

[18] Adair, E. R.; Mylacraine, K. S., and Cobb, B. L. Partial-body exposure of human volunteers to 2450 MHz pulsed or CW fields provokes similar thermoregulatory responses. Bioelectromagnetics. 2001 May; 22(4):246-59.

frequencies directly (exposure to 100 MHz) (*Adair and Black 2003; Allen et al., 2003*), they do underscore the authors' opinion that 'the thermoregulation capacity of humans is greater than any other living organism tested'. This shows, once again the 'conservative' nature of extrapolations from animals to humans.

Mobile telephones and the skin: *Monfrecola et al.* (*2003*) and *Roelandts* (*2003*) observe a significant increase in micro-circulatory blood flow in the outer ear in human volunteers, proportional to the level of activity of the telephone (from 61 per cent at the start up to 158 per cent when the telephone is in communication mode), and that this is reversible. At the same time, 27 out of 30 subjects developed reddening and a sensation of heat at the auricle. Unfortunately, a comparative test with fixed telephones should have been used for control. Nothing can be concluded as to skin cancers. The question of long-term or cumulative effects is posed.

In the cardio-vascular area, few publications have appeared. The Turkish publication by *Celik and Hascalik (2004*) presents a study of the effects of mobiles on the basic heart rate of the foetus, accelerations and slowing. Forty pregnant women not subject to any stressing test were examined. They held the mobile, either switched off or in use for 10 minutes. The result was an absence of any effect on fœtal heart rate, neither acceleration nor slowing. The problem is of interest, but a more rigorous methodology and more accurate measurement would be required before a conclusion on innocuousness could be accepted. It should also be emphasized that this type of study raises ethical issues.

In a Finnish study by *Tahvanainen et al.* (*2004*), the authors recall a recent investigation mentioning the danger of increased blood pressure after 35 minutes of exposure to a GSM-900 signal. The authors carried out a double blind experiment with 32 healthy subjects exposed to the GSM-900 (1.6 W/kg) and 1800 (0.7 W/kg) and to a sham exposure (telephone switched off), in separate sessions. They measured blood pressure (with a sphygmomanometer) and heart rate during and after 35 minutes of exposure (real or sham). The cardiovascular responses were monitored in terms of pressure, heart rate during controlled breathing, spontaneous breathing, Valsalva technique, hyperpnea and tilt table test. Blood pressure and heart rate were not significantly altered during the 35 minutes and even after exposure to 900 or 1800 MHz, in relation to the sham exposure.

Haarala et al. (2003b), present a pioneering study of cerebral blood flow by PET[19] on 14 right-handed subjects, in double blind manner. During the PET scan, the subject carried out a visual memory task. Exposure to an active mobile phone produced a relative decrease in regional cerebral blood flow bilaterally in the auditory cortex but no modification in the area of maximum exposure. It may be that the radiofrequencies have an artefact effect on the acquisition system. The authors admit that this work needs to be followed up. This is probably in a difficult area where identification of instrumental artefacts will be essential if acceptable conclusions are to be hoped for.

5.2.4 Human biology parameters

Rather curiously, research into biological or serous parameters have not, to our knowledge been the object of any new investigations in humans.

5.2.5 Case studies

[19] Positron emission tomography

Case studies are interesting in that they attract attention to a question, particularly when observations from *different horizons* are repeated: they then allow the building of a hypothesis that will serve for the development of epidemiological or experimental studies. At no time, however, can a case study be taken as proof of a cause-effect relationship, with the exception of acute problems when the removal of exposure leads to an obvious disappearance of symptoms.

In the area of mobile telephony, several publications often by the same authors, *Westerman and Hocking, (2004)* indicate localized symptoms that have been studied in the epidemiological studies mentioned above. Some anecdotal accidents (burns) arising from improper use of the mobile telephone have also been reported (*Potokar, 2003* ; *Kato, 2003; Seishima, 2003*).

5.2.6 Interference with driving

Numerous experimental studies have been carried out on the risk of accident to mobile telephone users: they all underscore the reduced vigilance caused by use, but to widely varying degrees and in very different circumstances.

In a study of 42 volunteers, *Hancock et al., (2003)*, demonstrate distraction due to mobile telephones: slowness to react, violent braking, failure to comply with road signs, the level of distraction varying, however, quite a lot from subject to subject. *Lesch and Hancock (2004)*, studied 36 volunteers, who had responded to an advertisement, by socio-demographic questionnaire and by age category and gender, using driving reaction time tests (braking distance, emergency stopping) and attention-memorization experiments. The allocation of frequency and perception of calls was done by the patient. The data were subject to variance analysis and Spearman rank test. The authors reveal differences between the sexes and between age categories (lower performance for women, older). Moreover, it appeared that the subjects were not aware of their reduced performance during a call.

Other far more nuanced opinions are now emerging. *Barkana et al. (2004)*, based on an original method for evaluation of attention performance in the field of vision, prove that used of the hands-free cell phone significantly reduces attention, but only in certain subjects. They suggest, in summary, that banning the use of telephones while driving should be suited to individual cases (but on what basis?). *Matthews et al. (2003)* also conclude from their study (of 13 volunteers) that use of the hands-free kit results in less interference between the functions of driving and telephoning.

5.2.7 Conclusions on experimental studies on humans

At the end of this examination, we would have liked to be able to extract some new ideas from the results, which are mostly negative, but which are almost all marred by uncertainty. It is clear that too many investigations suffer from a severe lack of accurate dosimetric data. Dosimetry is not easy, but it is where efforts must be concentrated—only studies carried out in globally identical conditions of exposure will, by way of comparison, bring us closer to a verdict. It is worthy of note that some tests shown an effect favourable to performance. Elsewhere, investigations indicate altered markers (especially electro-physiological) whereas the behavioural tests are normal, suggesting that either the behavioural tests are not sensitive enough, or they have no precise relationship with the markers.

5.3 New animal data

5.3.1 Nervous system and behaviour

5.3.1.1 Haematoencephalic barrier

Studies of the integrity of the haematoencephalic barrier (HEB), especially at low exposure levels, have not so far produced any definitive conclusions. *Salford et al., (2003)* exposed rats for 2 hours to a GSM-900 signal, at non-thermal level, and observed increased permeability of the HEB. Several replication studies are pending publication or studies are in progress, and it will be another year or so before the results are available. The assessment that we can draw up today (see review by *D'Andrea et al. 2003* and the Reisensburg workshop) is that the effects on the HEB seem only to occur at thermal level. Very recent confirmation of this has come from the Cassel group in Strasbourg which, as part of the European Perform-B programme, obtained negative results[20], using an indirect method for assessment of the permeability of the HEB in rats exposed to 2.45 GHz, as in Lai's experiments on memory.

Author/Review/Title	***Source/SAR/Dosimetry***	***Animal model - Method***	***Results***
Salford LG, Brun AE, Eberhardt JL, Malmgren L, Persson BR, Environ Health Perspec, 2003, 111(7):881-3 *Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones.*	- source: GSM maximum power (2 hours, tem - SAR: 0.2−2.20 mW/kg - Dosimetry by FDTD	***Fisher Rats*** (24) - development 50d before sacrifice Neuronal integrity in cortex, hippocampus, basal ganglia and hemispheres Anomalies (passage of albumin) judged semi-quantitatively. Statistics: non-parametric tests (Kruskall Wallis or U)	Significant neuronal lesions (p<0.02%)

5.3.1.2 EEG

As previously, modified EEG spectra are found at thermal level powers (*d'Andrea et al., 2003*) with the exception of the Marino group (*Marino et al., 2003*), which observed brief loss of structure of EEG (300 ms) in rabbits. However, the scope of these findings is severely limited by the failure to characterize the exposure system and by the absence of dosimetry.

Author/Review/Title	***Source/SAR/Dosimetry***	***Animal model - Method***	***Results***
Marino AA, Nilsen E, Frilot C, 2003, 24(5) :339-46. Bioelectromagnetics *Non linear changes in brain electrical activity due to cell phone radiation*	- source: TDMA (824-849 MHz 600 mW max. radiated - Antenna connected to telephone placed 1cm above head - SAR: actual field not measured - No dosimetry	***Rabbit*** (10) -EEG Non-linear EEG analysis method (integration of spatial phases): comparison of areas with controls -statistics: comparison of controls/exposed times; Wilcoxon W test	The effects (random alteration of EEG) appear at 100 ms and last 300 ms. At the same time, the EEG is de-structured. No effect if telephone placed on thorax. Author's conclusion: effects appear linked to absorption of waves by

[20] Cosquer B, Pereira de Vasconcelos A, Fröhlich J, Cassel J-C. Blood-brain barrier and electromagnetic fields: effects of scopolamine methylbromide on working memory after whole-body exposure to 2.45 GHz microwaves in rats. Behavioural Brain Research (soumis et rapport Perform B)

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
			brain

5.3.1.3 Learning, behaviour, memory

D'Andrea's review (*2003*) emphasized the importance of choice and control of experimental criteria, as well as the observable (test) in question. With this in mind, the attempts to replicate Lai's experiments did not show any effect (*Cobb, 2004*), or modification of the cognitive tests (mazes, learning) when levels are not thermal (or near to the limits) and controlled (*Dubreuil et al., 2003 ; Yamaguchi H et al., 2003*).

The Cassel group carried out a set of experiments using the Lai exposure system and, like him, a 12-arm maze. No changes in learning were observed (*Cassel et al., 2004 ; Cosquer et al., 2004*).

Very recently, Lai has published a new observation (2004) on altered learning and short-term spatial memory in rats exposed to 2.45 GHz CW (1.2 W/kg, 1 hour before test), which is eliminated in the presence of a magnetic field (incoherent noise between 30 and 90 Hz, 60 µT). In spite of good statistical analysis, the failure to mention the dosimetry method limits the scope of these results. After looking at all of Lai's experiments based on the same protocol (except for the magnetic noise) and which could not be replicated, validity of this new investigation is not proven.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
Cobb Bl, Jauchem Jr, Adair Er, Bioelectromagnetics, 2004, 25(1) :49-57 *Radial arm maze performance of rats following repeated low level microwave radiation exposure*	-source: 2.45 GHz, 45minutes/d, 10d 2µs pulses, 500pps, - SAR 0.6 W/kg. -dosimetry by differential measurement of absorption on carcasses in the rat's three possible axes of orientation. **Replication H.Lai (1994)**	***Sprague-Dawley Rats*** - observation of performance in maze over 10d, completion and errors 8 rats per group Modulation by associated drugs: physiostigmine, naloxone chloride, naloxone metodide, or salt water - statistics: Variance analysis (ANOVA, 3 methods) taking account of different factors (exposure, day, drug, intragroup, etc...)	Completion took longer with naloxone chloride and physiostigmines. No microwave effect, especially on secondary effects of drugs (to lethal doses of physiostigmine)
Yamaguchi H, Tsurita G, Ueno S, Watanabe S, Wake K, Taki M, Nagawa H, Bioelectromagnetics, 2003, 24(4) :223-30 *1439 pulsed TDMA fields affect performances of rats in maze task only when body temperature is elevated*	-source: TDMA 1.439 GHz, carousel; 50 Hz pulse train, duty factor=1/3, pulses 6, 7 ms) - brain SAR (7.5 W/kg (total SAR = 1.7 W/kg) or 25 W/kg (5.7 W/kg) 45 min/d 4d -dosimetry: FDTD (phantoms) and temperature measurement.	***Sprague-Dawley Rats*** T maze with choice and reward Errors (inverse learning) Temp. measurement: intraperitoneal Evaluation of learning over short (4 days) and long term (weeks). - statistics: variance analysis (ANOVA) and Neuman's Keul (post-hoc, between groups)	Increase in errors only when temperature is raised (20 W/kg). Conclusions: in the operating conditions (2 W/kg−10g tissue) no thermal effect expected

Author/Review/Title	*Source/SAR/Dosimetry*	*Animal model - Method*	*Results*
Dubreuil D, Jay T, Edeline Jm, Behav Brain, 2003, 145(1-2): 51-61. *Head only exposure to GSM 900 MHz EMF does not alter rats' memory in spatial and non-spatial tasks.*	-source: GSM 900, 45 minutes, 1 to 3.5 W/kg Head SAR: 1 or 3.5 W/kg -dosimetry: measurement with Vitek probe and FDTD calculation (phantoms)	***Rats Sprague-Dawley*** -spatial and non-spatial learning tasks; -maze with confinement between each arm visit; -after 15 min, introduction into test after visit of 4 arms; - object recognition test -statistics: Variance analysis (between groups, between subjects) after normality check	Discordant results (exposed/control differences at 3.5 W/kg, but not with control group), contradicted by second experiment A thermal effect explaining these responses is not totally excluded. No effect of exposure on performance
Cassel JC, Cosquer B, Galani R, Kuster N (2004). Behav Brain Res. 155: 37-43. *Whole-body exposure to 2.45 GHz electromagnetic fields does not alter radial-maze performance in rats*	2.45 GHz, pulsed (2 µs, 500 pps, 0.6 W/kg) 45 min/day exposure before test **Replication H.Lai (1994)**	***Sprague-Dawley Rats*** 12-arm maze Working spatial memory test	No effect
Cosquer B, Galani R, Kuster N, Cassel JC (2005) Behav Brain Res. 156:65-74. *Whole-body exposure to 2.45 GHz electromagnetic fields does not alter anxiety responses in rats: a plus-maze study including test validation.*	idem	***Rats Sprague-Dawley*** Raised, + form maze Anxiety test	No effect

5.3.2 Neuro-degenerative pathologies

The WHO has recommended experiments on animal models for neuro-degenerative pathologies. However, corresponding validated models are rare, and only one study has been conducted to date. The experimental allergic encephalomyelitis (EAE) rat model (progressive paralysis associated with alteration of general condition, reversible in 15 days) was used with the GSM-900 signal (up to 6 W/kg, 2 h/d, 21 days) without any radiofrequency effects being observed (except for possible reduction in stress factor) on the EAE attack (*Anane et al., 2003*).

Author/Review/Title	*Source/SAR/Dosimetry*	*Animal model - Method*	*Results*
Anane R, Geffard M, Taxile M, Bodet D, Billaudel B, Dulou PE, Veyret B, Bioelectromagnetics, 2003, 24(3): 211-3. *Effects of GSM-900 microwaves on the experimental allergic encephalomyelitis (EAE) rat model of multiple sclerosis*	- GSM 900 (mod 217 Hz), antenna loop on head 21d, 2h/d - local SAR 1.5−6 W/kg -dosimetry by measure on phantom and (FDTD) calculation	***Lewis female rats***, familiarization with system Recognized EAE model of multiple sclerosis EAE induced by mixture of myelin basic protein and Mycobacterium tuberculosis	No effect on onset and development or end of attack. In animals not familiar with constraint, appearance of a stress-related response, seemingly reduced at 1.5 W/kg exposure.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
			This stress effect is not present in familiarized animals (7 d).

5.3.3 Peroxidation, free radicals

In the genesis of elementary lesions linked to exposure, mention is made of actions on the concentration of reactive oxygen species (ROS), and the resulting modifications of oxidative status. Recently published studies are not of sufficient quality regarding either their choice of models and methods, and dosimetry.

Only studies conducted with modern physical and biological methods can indicate whether these alterations of ROS concentrations are caused by exposure to low level radiofrequencies. Such experiments are carried out frequently in the ELF range.

Author/Review/Title	Source/SAR/Dosimetry	Animal model – Method	Results
Aweda MA, Gbenebitse S, Niger Postgrad Med J, 2003, 10(4) :243-6. *Effects of 2.45 GHz microwaves exposure on the peroxidation status in Wistar rats*	- source: 2.45 GHz, CW, duration: 1h 8 weeks monitoring - SAR: power density 6 mW/cm^2 Dosimetry?	***Wistar Rats*** Lipidic peroxidation status (TBA method)	Increase in lipidic peroxidation Protective effect of vitamins C and E

5.3.4 Cancers and genotoxicity *in vivo*

Studies of carcinogenesis examine either the direct effect or promoter role of radiofrequencies in the presence of identified carcinogens.

Study of the action of radiofrequencies alone has been the subject of three publications. The first study, by *La Regina et al. (2003)* used normal rats subjected to chronic exposure to two American radiotelephone signals (835 MHz TDMA or 832 MHz CDMA). No effects were observed on the animals' weights or incidence of tumours. This study is all the more valuable as its protocol and dosimetry are well detailed. The second study is that by *Sommer et al. (2004)*, on mice genetically predisposed to develop lymphoma. Whole body exposure of the animals for 5.5 months to GSM-900 showed a minimal effect on weight gain but no effect on development of lymphoma. A third group took an interest in the iridium signal at 1.8 GHz. Although the signal has been abandoned, the study is interesting from several points of view: it uses a frequency higher than those studied to date (800−900 MHz) and includes *in utero* exposure. Rats were subject to far-field exposure from the 19th day of gestation until weaning, then males and females from the litter were exposed head-only (0.16 and 1.6 W/kg) from the age of 36 days to 2 years. Survival in the litters, histopathological evaluation of the brain and main tissues, as well as weight monitoring, revealed no difference between exposed animals and those in the control group. Only a longer survival time was observed for exposed females.

Two studies are also available on the promoter effects of radiofrequencies on induced cancer models. *Heikkinen et al. (2003)* did not show any significant effect on promotion of tumours in mice after simultaneous exposure to a GSM signal with SAR of 0.35 W/kg RF and X rays[21]. In their recent study, they assess the effect of simultaneous exposure to UV and radiofrequencies (GSM-900, SAR 0.5 W/kg) on populations of normal or transgenic mice for the enzyme ornithine decarboxylase (ODC), which is overexpressed in skin cancer. No difference was found in the frequency of skin tumours, but the authors did note a non-significant acceleration in tumour growth rate in the non-transgenic mice and, according to the authors, the study is worthy of replication. The article by *Anane et al.* covers promotion of mammarian tumours induced by DMBA (a known chemical carcinogen) in female rats subjected to semi-chronic exposure to GSM-900 (whole body). The latency, multiplicity and volume of tumours do not appear to be altered for SARs below 1.4 W/kg. For higher SARs, increased incidence of malignant tumours is observed. However, the contradictory results for SAR of 1.4 W/kg, common to both sets of experiments, make it difficult to draw conclusions. The potential importance of these results, presented at a conference prior to publication, has motivated the setting up of two studies for their confirmation, in China (study financed by the MMF) and in Austria (European Union Perform-A study). The results of these studies will be announced in the coming months.

The study of exposure to SARs higher than environmental or authorized exposure levels appears essential for the possible detection of a critical effect (in the ICNIRP sense of the word) other than that observed in animal behaviour, documented from 4 W/kg, whole body.

Two *in vivo* studies have been conducted of genotoxic effect of radiofrequencies at 2450 MHz. The first used a transgenic pregnant mouse model, evaluating, in mice from the litters, the number and nature of mutations of the lacZ gene in the different organs, including the brain, after intermittent exposure to radiofrequencies at 0.7 and 1.4 W/kg, whole body (*Ono et al., 2004*). The second study is a replication of the work by Lai and Singh (1995)[22] evaluating damage to DNA (comet assay) in the brain cells of rats subjected to acute exposure at 1.2 W/kg, whole body. No mutagenic or genotoxic effects were revealed by these studies. In particular, the previous work by Lai and Singh was not confirmed. It is worth recalling that this work was the subject of a negative replication by *Malyapa et al. (1998)*[23].

Author/Review/Title	***Source/SAR/Dosimetry***	***Animal model - Method***	***Results***
Anane R, Dulou PE, Taxile M, Geffard M, Crespeau FL, Veyret B, Radiat Res, 2003, 160(4) :492-7. *Effects of GSM900 microwaves on DMBA induced mammary gland tumours in female Sprague-Dawley rats.*	- Exposure to radiofrequencies, 2h/d-5d/9wks 10 d after DMBA (10mg/kg). - Source: GSM 900, base station antenna placed 1.80 m above the rats. -SAR: 2 experiment groups 16 rats per group Set 1: sham, 1.4−3.5−2.2 W/kg Set 2: sham, 0.1-0.7-1.4 W/kg - Dosimetry in far field conditions; use of phantoms; multifocal determination of local SAR and whole body SAR.	**Sprague-Dawley female rats** Sacrifice 21 days after end of exposure Weighing, regular observation of tumours Histopathological study of mammary gland tumours, blind manner	No effect on latency or on number and volume of tumours up to 1.4 W/kg where opposite results are observed between the two experiment sets. Above 1.4 W/kg whole body, the incidence of tumour increases, without dose-effect relationship.

[21] Heikkinen, P., V.-M. Kosma, et coll. (2001). "Effects of Mobile Phone Radiation on X-Ray-Induced Tumorigenesis in Mice." Radiat Res 156: 775-785.
[22] Lai, H. and P. Singh N (1995). "Acute Low-Intensity Microwave Exposure Increases DNA Single-Strand Breaks in Rat Brain Cells." Bioelectromagnetics 16(3): 207-210.
[23] Malyapa, R. S., E. W. Ahern, et coll. (1998). "DNA Damage In Rat Brain Cells After *In vivo* Exposure To 2450 MHz Electromagnetic Radiation And Various Methods Of Euthanasia." Radiat Res 149: 637-645.

Author/Review/Title	***Source/SAR/Dosimetry***	***Animal model - Method***	***Results***
Anderson LE, Sheen DM, Wilson BW, Grumbein SL, Creim JA, Sasser LB. Radiat Res., 2004, 162:201-10 *Two-year chronic bioassay study of rats exposed to a 1.6 GHz radiofrequency signal.*	- Source: Iridium 1.6 GHz 160 pregnant rats Far field exposure of fœtus then young of litters SAR in brain: sham, 0.16 W/kg: start at 19 d gestation and until age 23 d (weaning).2 h/d, 7 d/week Separation of litters into 2 groups of 90 males and 90 females Near field exposure: SAR: sham, 0.16 or 1.6 W/kg 2 h/d, 5 d/week from 36th day to age 2 years Cage control (80 males, 80 females) -Statistics: variance analysis of continuous parameters, Kaplan - Meier method on survival data.	**Pregnant Fisher rats and their litters** Number of live rats in litters Monitoring of weight Complete necropsy of all rats (spontaneous death, moribund or at end of experiment) Sampling of all tissues and tumours for blind histological evaluation.	No significant difference between groups regarding numbers of live rats in litters, survival index, and weight, nor for different clinical signs or cancerous lesions. In males, no difference in survival at end of exposure. In females, significant reduction in survival time in controls.
Heikkinen P, Kosma VM, Alhonen L, Huuskonen H, Komulainen H, Kumlin T, Laitinen JT, Lang S, Puranen L, Juutilainen J, Int. J . Radiat. Biol, 2003, 79(4): 221-33. *Effects of mobile phone radiation on UV-induced skin tumourigenesis in ODC transgenic and non-transgenic mice*	Source: DAMPS (digital advanced mobile phone system) GSM 900 1.5 h/d, 5 d/week, 52 weeks SAR: 0.5 W/kg, + UV: 240 J/m^2, 3 times/week	**K2 ODC transgenic mice** (overexpressed ornithine decarboxylase gene) **and normal mice** Controls: 20 mice Other groups: 45−49 mice Palpation + histopathology of lesions Assay of 6-OH-melatonin sulphate (melatonin metabolite) Assay of cutaneous polyamines	No effect on development of tumours, nor on excretion of 6-OH-melatonin sulphate, nor level of cutaneous polyamines.
La Regina M, Moros EG, Pickard WF, Straube WL, Baty J, Roti Roti JL, Radiat Res, 2003, 160(2) :143-51 *The effect of chronic exposure to 835.62 MHz TDMA or 847.74 CDMA RF radiation on the incidence of spontaneous tumours in rats*	835.62 MHz TDMA 842.74 MHz CDMA 4 h/d, 5 d/week, 2 yrs. Average SAR in brain: 1.3 W/kg, monitored in different areas and corrected for movement - Dosimetry by thermographic and thermometric measurement -Statistics: Number and incidence (Fisher), weight (variance analysis), survival (Kaplan-Meier and Cox), treatment/ 1 tumour relationship (Pearson), treatment/number of tumours (Kruskall-Wallis)	**Fischer 344 rats** 40 males /40 females Global (weight) and histological evaluation of major organs (brain, spinal cord, adrenal glands, oesophagus, heart, stomach, intestines, kidneys, liver, lungs, lymph nodes, nasal cavities, reproductive organs, pancreas, salivary glands, spleen, thymus, thyroid, trachea and bladder). In cases of anomalies in other organs, samples were taken for histopathological examination. Very closely detailed	No incidence on weight nor in incidence of tumours in exposed animals compared with controls.

Author/Review/Title	*Source/SAR/Dosimetry*	*Animal model - Method protocol*	*Results*
Sommer AJ, Streckert J, Bitz AK, Hansen VW, Lerchl A. BMC Cancer, 2004, 4 :77-89 *No effects of GSM-modulated 900 MHz electromagnetic fields on survival rate and spontaneous development of lymphoma in female AKR/J mice*	-Source: GSM 900 MHz, radial wave guide, animals not restrained SAR: 0.4W/kg, whole body ± 40% - Exposure: 24 h/d, 7d/week, start at 6 months until 11.5 months - Dosimetry: calculation for 5 position configurations - Statistical tests: Multiple regression analysis and unpaired Student t test (weight loss), Kaplan and Meier (survival), ANOVA 2 channels (blood count)	***AKR/J`transgenic mice*** - weighing of animals and weekly palpation of tumours - monthly blood samples (from 6 months) for blood count At sacrifice (CO_2): necropsy, fixation and histology of tissues (spleen, thymus, lymph nodes, liver, kidneys, lungs, brain).	- No significant difference in survival rates - No significant difference in incidence of lymphoma - No significant difference in blood counts - Weight increase in animals exposed to radiofrequency
Lagroye I, Anane R, Wettring BA, Moros EG, Straube WL, Laregina, Niehoff M, Pickard WF, Baty J, Roti Roti JL, Int J Radiat Biol, 2004, 80(1) :11-20 *Measurements of DNA damage after acute exposure to pulsed waves 2450 MHz in rat brain cells by two alkaline comet assay methods*	- Source: 2450 MHz. SAR: 1.2 W/kg, whole body - Exposure: 2 h, sacrifice 4 h after exposure Positive control 1Gy of ^{137}Cs, (gamma). - Dosimetry: calculation, and temperature measurement **Replication of Lai and Singh, 1995**	**Male Sprague-Dawley rats** - Observation of DNA damage in brain cell suspension: comet assay - Two variants (± Proteinase K) of alkaline comet assay method to check for presence (or not) of DNA-protein links	- No change in lengths of comets, nor of standardized comet moments. - No lesions (detectable by alkaline comet method) ascribable to radiofrequency exposure
Ono T, Saito Y, Komura J, Ikehata H, Tarusawa Y, Nojima T, Goukon K, Ohba Y, Wang J, Fujiwara O, Sato R. *Tohoku J Expl Med,* 2004, 92(19) :93-103 *Absence of mutagenic effects of 2.45GHz RF exposure in spleen, liver, brain and testis of lacZ-transgenic mouse exposed in utero*	Source: 2450 MHz, intermittent - exposure16h/day, from 0 (conception) to 15d *in utero*, examination 10 weeks after birth - SAR: 0.71 W/kg, whole body:10 sec on /50 sec off or 1.4W/kg, whole body: 20 sec on /40 sec off (to avoid thermal effects), - Dosimetry: measurement + FDTD (4.3 W/kg, continuous) rectal temperature monitored ($\Delta T \leq 0.43$°C)	**Pregnant lac-Z transgenic mice exposed in utero** - Observation of lacZ gene mutations in spleen, liver, testis, brain - Sequencing of nucleotides in mutants (PRISM377) and comparison with wild type	- No difference compared to non-irradiated control group, either quantitative or qualitative (nature of mutations)

5.3.5 Reproduction-development

With the exception of the thermal effects identified, previous studies have not shown evidence of post-natal effects due to pre- or perinatal exposure of animals to GSM (2003 report). The investigation proposed by *Dasdag et al. (2003)* covers in vitro exploration of the functional, histological consequences in rat testes of total exposure at a low level (0.52 W/kg over 1 g). No effect was found. Similarly, in controlled dosimetry conditions (temperature, FDTD) the *Ono (2004)* group was not able to show any major consequences (deletions, recombination) in mutations in lac-Z mutant mice exposed during gestation (up to 0.71 W/kg). In parallel, *Nakamura et al. (2003)* only observed disturbance in placenta circulation, immune functions and hormonal secretions (oestradiol, progesterone) at thermal effect levels. Furthermore, at these levels, the modifications of parameters are no different from those obtained by simple raising of temperature (immersion in water at controlled temperature).

Conversely, the study by *Pyrpasopoulou et al. (2004)* showed modifications to the expression of renal protein genes (BMP-1 and -2) in new-born rats irradiated during gestation with, however, a very low SAR (5×10^{-4} W/kg). In addition, the fact of choosing a higher frequency (9.4 GHz) to take account of the animal's size does not take account of the differences in the dielectric properties of the tissues, which depend on frequency. Interpretation of these data is therefore very difficult.

To sum up, most effects only appear at thermal levels. However, the existence of effects at low levels cannot be excluded and would benefit from replication and use of larger animals (at different frequencies) to evaluate the factor for possible transposition to humans.

Author/Review/Title	***Source/SAR/Dosimetry***	***Animal model - Method***	***Results***
Dasdag S, Zulkuf AM, Aksen F, Yilmaz F, Bashan M, Mutlu S, Dasdag M, Salih CM, Bioelectromagnetics, 2003, 24(3):182-8 *Whole body exposure of rats to microwaves emitted from a cellular phone does not affect the testis*	- Source: mobile at 0.5 cm under rat cage 20 min/d 1 month - Total SAR 0.52 W/kg (over 1g), 3.13 W/kg peak - Dosimetry : Calculation by FDTD on ellipsoid model. Monitoring of heterogeneity of power emitted by 'cell sensor'	***Rats-testes*** Lipidic composition, MDA P53 (immunohistochemistry), spermogram, morphology/histology Rectal temperature - Statistic Randomization 8 T/8 exposed U-Mann Whitney test	No significant difference
Nakamura H, Matsuzaki I, Hatta K, Nobukuni Y, Kambayashi Y, Reprod toxicol, 2003, 17(3):321-6 *Non thermal effects of mobile phone frequency microwaves on uteroplacental functions in pregnant rats*	-Source: 915 MHz (magnetron, 90 minutes exposure), The rats were placed in plexiglass tubes parallel to the antenna The rats were divided, at random, into 6 groups of 6: -exposure to 0.6 mW/cm^2 (SAR estimated at 0.4W/kg, whole body) -exposure to 3 mW/cm^2 (estimated SAR 2W/kg, whole body) - rats immersed in water at 38°C (temperature corresponding to rise resulting from exposure to 0.6 mW/cm^2) -rats immersed in water at 40°C (temperature corresponding to rise resulting from exposure to 3 mW/cm^2) - rats immersed in water at 34°C (neutral thermal conditions) - control rats Temperature measured by intra-rectal thermistor. - Dosimetry by calorimetry	**Pregnant RATS** - Measurement of placental and uterine circulation - immune function (spleen NK cells) - Hormones (œstradiol and progesterone)	Differences between 34° and 38° groups, thermal in origin No difference between 6W/m^2 and 38°C Significant reduction in œstradiol and uteroplacental blood flow between 40° and 30 W/m^2 Reduced NK activity at 0.6 mW/cm^2 (considered as normal adaptive response) not found again at 3 mW/cm^2 (unexplained) Conclusion: no non-thermal effect for ANSI standards (0.6 mW/cm^2 or 4 W/kg, whole body)

Commentaire : These are W/cm^2, which seems unlikely, or mW/cm^2. In any case, everything should be expressed in W/m^2 to be consistent with the European units. G.D.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
Pyrpasopoulou, A, Kotoula V, Cheva A, Hytiroglou P, Nikolakaki E, Magras I, Xenos TD, Tsiboukis TD, Karkavelas G, Bioelectromagnetics, 2004, 25 :216-227 *Bone morphogenetic protein expression in new born rat kidneys after prenatal exposure to RFR*	- Source: exposure to 9.4 GHz (considered as GSM-like for rat, to take account of size factor: 900 MHz-human: ?) - Max. SAR 0.5 mW/kg. 20 µs pulses, RR=50 Hz Installation with two sources to monitor standing waves Dosimetry: spectral analyser FDTD	***Wistar female rats*** Methods: immunohistochemistry, RT-PCR and in situ hybridization - Statistics: non-parametric tests (Mann-Whitney, Kolmogorov Smirnov) ; t-independent and semi-quantitative tests (Pearson – ki2 and V-Cramer)	Changes in expression of BMP-4 and its BMPR-I1 –II receptor when exposure is at start of gestation. In the absence of subsequent (functional) consequences, this could only mean a delay in renal development.

5.3.6 Expression of heat shock proteins (HSP)

No new element completes the rare *in vivo* studies of heat shock proteins (HSP). De Pomerai has confirmed, at several scientific meetings, that he has not been able to replicate his observations of increased expression of hsp16 in nematodes, after correcting his exposure system. There is therefore, at present, no proof of increase of HSP in animals under the effect of low-level radiofrequencies (see results obtained *in vitro*, below). The work of *Weisbrot et al., (2003)* mentioned in the table below was of poor quality, especially where the exposure system was concerned.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
Weisbrot D, Lin H, Ye L, Blank M, Goodman R, J.Cell Biochem, 2003, 89(1) :48-55 *Effects of mobile phone radiation on reproduction and development of drosophila melanogaster*	- Source: GSM 1900 MHz antenna placed along the outside of breeding tubes, perpendicular to their axis Test with telephone alone or associated with Tecno AO MP12 system blocking RF emission - Exposure 2x60 min/d, 10 days between egg and and nymph stages SAR: 1.4 W/kg given by manufacturer (SAR measured in human head phantom) - Dosimetry: Electric field measured in HF and ELF spectra by spectral analyser	***Fruit flies* (drosophila melanogaster)** - expression of gene hsp 70 - link activity with serum response element (SRE) - ELK-1 phosphorylation (nuclear transcription factor)	Increase in all parameters studied and increase in number of larvae in group exposed with telephone only Non-thermal effect Disappearance, according to the authors, of effects with system blocking radiofrequency emissions, of which the ineffectiveness is now recognized!

5.3.7 Eyes

The appearance of ocular lesions, ulcers or cataracts, mentioned in cases of accident provided a basis for recommendation of medical examination after over-exposure. Elder's review (2003), which covers a large number of models from the rat and rabbit to primates and humans, shows that the existence of immediate and long-term effects is linked to a local rise in temperature due to an elevated level of exposure (2.45 GHz, 150 W/kg in rabbits, for example). Recent studies on humans do not accept the link between exposure and cataract or cancer.

In this context the Kojima study (2004), using rabbits, anaesthetized or not, at high levels (1 hour, 2.45 GHz, to 75 W/kg at the sclera) provides little gain, as the known thermal effects are found, exacerbated by the reduced periaqueous and perivitreous perfusion linked to the anaesthetic.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
Kojima MI, Hata I , Wake K, Watanabe SI, Yamanaka Y, Kamimura Y, Taki M, Sasaki K, Bioelectromagnetics, 2004, 25(3) :228-33. *Influence of anaesthesia on ocular effects and temperature in rabbit eyes exposed to microwaves*	- Source: 2.45 GHz 20−60 mn, 300 mW/m^2 - SAR 108 W/kg, whole eye Local SAR: varies in accordance with area considered (from 75 W/kg at the sclera to 141 W/kg in fore chamber) - Dosimetry: FDTD	***Rabbit*** Unilateral exposure With or without anaesthetic (Ketamine/xylazine) Examination of rear segment of cornea and crystalline lens	Conjunctival myosis inflammation, diffraction of light in front cortex, reversible after one week More marked in the anaesthetized eye, linked to greater increase in temperature Thermal effects

5.3.8 Hearing

Kizilay et al. (2003), like *Marino et al.* (see 2003 Report) before them, were interested in otoacoustic emissions (activity of hair cells in the organs of Corti) in rats exposed to a GSM-900 signal (30 days, 1 hour per day). The results, also negative, are of limited validity, given the low numbers in the study, absence of dosimetry and comparison of dissimilar groups (newborns exposed and adult controls).

Aran et al. (2004) studied the effects on guinea pigs of localized semi-chronic exposure (one ear, loop antenna, GSM-900, SAR 1, 2 and 4 W/kg, 1 hour per day, 5 days per week for 2 months). Functioning of each ear was assessed either by otoacoustic emissions or brainstem auditory evoked potentials. In spite of the small number of animals in each group, the abundance of measurements allowed a good quality statistical study. No difference was found between the exposed and unexposed ears. A preliminary study did not show effects of exposure (900 MHz, 1 W/kg, for 24 hours, exposure system described by *Laval et al., 2000*[24]) on the *in vitro* development of organs of Corti in newborn rats.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
Kizilay A, Ozturan O, Erdem T, Kalcioglu MT, Miman MC, Auris nasus larynx , 2003, 30(3) :239-45. *Effects of chronic exposure of EMF from mobile phones on hearing in rats*	- Source: GSM 900, 1h/d, 30d Telephone placed at centre of tube containing rats, arranged radially, noses towards telephone - SAR used (based on 'manufacturer's' information): 0.95W/kg, not calculated or measured.	***Rats*** Adults (7 exposed and 7 controls or newborn (4) Measurement of otoacoustic emissions (from sense cells of inner ear)	No effect on outer or middle ear or cochlea for chronic exposure Newborns compared to adult control group (?)
Aran, J.-M.; Carrere, N.; Chalan, Y.; Dulou, P-E. Larrieu S. ; Letenneur, L.; Veyret, B., Dulon, D. International Journal of Audiology. 2004, 43(9) :245-254. *Effects of exposure of the ear to GSM microwaves: in*	Source: GSM 900 MHz *In vivo*: Loop antenna, Dosimetry by local temperature measurement, Exposure of one ear 1h/d, 5d/w, 2 months. *In vitro*: flat wire antenna, dosimetry with Vitek sensor	In vivo: ***Guinea pigs in waking state.*** Measurement of products of acoustic distortion and brainstem EAP. Statistical analysis. *In vitro*: ***organs of Corti in newborn rats.*** Evaluation (non-quantitative) of hair cell populations.	No effect

[24] Laval, L., Leveque, P. & Jecko, B. 2000. A new in vitro exposure device for the mobile frequency of 900 MHz. Bioelectromagnetics, 21(4), 255–263.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
vivo and in vitro experimental studies	Exposure 1W/kg, 24 hours		

5.3.9 Immunity

In 2003, Black and Heynick published an exhaustive review covering the effects on immunity in detail. Since the negative results obtained by *Gatta et al.* in 2003 and those of *Nakamura* (see § 5.3.5.1), no relevant new study has been published on the effects on the immune system.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
Gatta L, Pinto R, Ubaldi V, Pace L, Galloni P, Lovisoli GA, Marino C, Pioli C, Radiation research, 2003, 160(5) :600-605 *Effects of in vivo exposure to GSM-modulated 900MHz Radiation on mouse peripherical blood*	GSM 900 MHz, 2h/d-1-2-4 weeks GTEM cells, SAR: 1−2 W/kg Dosimetry: established by measurement and calculation, using phantoms and mice. Account taken of losses at each stage until precise evaluation of SAR, evaluated to within 20 per cent.	***C57BL-6 mice*** Spleen cells Populations B-T (CD4-CD8) + *in vitro* stimulation (LPS, monoclonal antibodies (activation, production of cytokines and expression markers)	None on populations Increase of gamma interferon at 1 week, not found again: adaptation not specific to stress. Conclusion: effect of exposure to GSM on immune system is improbable

5.3.10 Conclusions on animal studies

Since the previous report, no publication has reported harmful effects in animals.

The effects observed occur at thermal levels. The studies showing results at low levels are, for their part, frequently impaired by the lack of dosimetric information or biases relating to the protocol; some merit replication.

However, some results obtained at low levels continue to raise questions:

- The permeabilization of the HEB in rats exposed to mobile telephone signals is a phenomenon that has not been demonstrated in recent studies, but given its potential importance in terms of public health, the results of studies in progress should be awaited and further studies undertaken in the hope of reaching a conclusion.
- Where cancers are concerned, studies on the co-promotion of tumours in the presence of known carcinogens (X rays, UV and DMBA) do not show an effect of exposure on development of tumours. However, in the case of DMBA, it will be necessary to await the results of studies in progress before reaching a conclusion.

5.4 Cell studies

5.4.1Genotoxicity

Three studies have evaluated the genotoxic potential of low level radiofrequencies on the diverse cell models: human peripheral blood mononuclear cells (*Zeni et al., 2004*), Molt-4 human lymphoblastoma cells (*Hook et al., 2004*) and C3H 10T1/2 immortalized fibroblastic mouse cells (*Lagroye et al., 2004*). The tests used were comet assay and micronucleus test. These studies converge strongly on the absence of effects of radiofrequencies at 813 and 2450 MHz resulting in damage to DNA. Unlike the other confirming studies published recently, the results by *Phillips et al*. *(1998)*[25] are not found by *Hook et al.* Moreover, the *Lagroye et al.* study (2004) shows an absence of DNA-protein links after exposure to radiofrequencies. This argument put forward to explain the difference between *Lai and Singh's* results (*1995*) and those of *Malyapa et al.* (*1998*)[26] for observation of DNA damage can thus not be upheld (see Chapter 3).

If the intermittent nature of the signal appears to be a critical parameter for observation of DNA damage for *Zeni et al. (2004*), it must be borne in mind that an earlier study had, on the contrary, suggested the possibility of biological effects linked to modulation (*Ambrosio et al.*)[27]. Globally, few studies have yet been made of intermittent signals, but the multitude of possible on/off combinations makes the outlook for a systematic study difficult.

In a review of this subject, *Meltz* (2003) concludes that low intensity radiofrequencies are not genotoxic. He also recalls the advantage, in any publication, of describing the apparatus, dosimetry, SAR, type of emission, and temperature, as well as of using recognized and detailed experiment protocols, of indicating the number of repetitions, the controls used and the statistical tests applied.

Author/Review/Title	***Source/SAR/Dosimetry***	***Animal model - Method***	***Results***
Hook GJ, Zhang P, Lagroye I, Li L, Higashikubo R, Moros EG, Stra WL, Pickard WF, Baty JD, Roti Roti JL, Radiation Res, 2004, 161(2):193-200 *Measurement of DNA damage and apoptosis in Molt-4 cells after in vitro exposure to RF radiation*.	Sources: 847.74 CDMA, SAR: 3.2 W/kg 835.62 FDMA, SAR: 3.2 W/kg 813.56 iDEN®, SAR: 2.4 or 24 mW/kg 836.55 TDMA, SAR 2.6 or 26 mW /kg - RTL cell - Exposure: 24 h during exponential growth - T° controlled at 37±0.3°C - Dosimetry: calibration of SAR, of temperature and periodic checking with thermocouple. -Statistics: variance analysis **Replication of Phillips et al, 1998**	**Molt-4 human cells** - DNA damage detected by electrophoresis on isolated cells (alkaline comet test) - Apoptosis: annexine V test	No significant difference Negative replication
Lagroye I, Hook GJ, Wettring BA, Baty JD, Moros EG, Straube WL, Roti Roti JL, Radiat Res, 2004, 161(2) :201-14. *Measurement of alkali labile DNA damage and*	- Source: 2450 MHz CW, RTL cell SAR: 1.9W/kg - Exposure 2 h ± CDDP (cisplatine) or ^{137}Cs gamma irradiation (4Gy) - Dosimetry: rapid measurement of temperature differential and FDTD	**C3H-10T(1/2) mouse cells (fibroblasts)** - Search for lesions of DNA-DNA or DNA-protein cross links, DNA lesions - Comet test	No effects of radiofrequency on DNA lesions, DNA-DNA or DNA-protein links *This study shows that the absence of proteinase K in the*

[25] J.L. Phillips, O. Ivaschuk, T. Ishida-Jones, R.A. Jones, M. Campbell-Beachler, W. Haggren. DNA damage in Molt-4 T-lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro. Bioelectrochemistry and Bioenergetics, 45 :103–110 (1998).
[26] Malyapa RS, Ahern EW, Bi C, Straube WL, LaRegina M, Pickard WF, Roti Roti JL. DNA damage in rat brain cells after *in vivo* exposure to 2450 MHz electromagnetic radiation and various methods of euthanasia. Radiat Res. 1998 Jun;149(6):637-45
[27] d'Ambrosio G, Massa R, Scarfi MR, Zeni O. Cytogenetic damage in human lymphocytes following GMSK phase modulated microwave exposure. Bioelectromagnetics. 2002 Jan;23(1):7-13.

Author/Review/Title	Source/SAR/Dosimetry	Animal model - Method	Results
protein-DNA crosslinks after 2450 MHz micro-waves and low dose gamma irradiation in vitro	- Statistics: U Mann-Whitney and variance analysis	- ^{35}S incorporation test	*comet test cannot explain the differences between the results of Lai and Singh (1995) and those of Malyapa et al. (1998, see Chapter 3).*
Zeni, O, Chiavoni AS, Sannino A, Antonili A, Forigo D, Bersani F, Scarfi MR, Radiation Research, 2004, 160-2) :152-158 *Lack of genotoxic effects (micronucleus induction) in human lymphocytes exposed in vitro at 900 MHz EMF*	- Source: 900 MHz, CW or GSM calibrated TEM cell SAR: 0.2 et 1.6 W/kg - Exposure * CW and GSM, 1.6 W/kg = 44 h intermittent (6 min ON/ 3 h OFF, 14 cycles), cells stimulated with PHA * GSM, 1.6 W/kg=24 h intermittent (6 min ON/ 3 h OFF, 14 cycles), cell not PHA stimulated * GSM, 0.2 W/kg=1h/day, 3 days, cells stimulated with PHA - Dosimetry: calculation by FDTD - max. ΔT measured 0.5 ℃, but no real temperature monitoring - Statistics: paired Student test, Wilcoxon test	**Peripherical blood lymphocytes from donors** - 4 to 7 donors per exposure class - Micronucleus test (binucleic cells) and cytotoxicity (proliferation index)	No significant difference for micronucleus induction or proliferation index.

5.4.2 Apoptosis, genes and proteins

The first studies of the effects of low SAR radiofrequency exposure on the process of apoptosis have been published. Apoptosis, or programmed cell death, is recognized as a biological phenomenon of fundamental importance for living organisms. In fact, homeostasis[28] can be considered as the result of a balance between cell proliferation and apoptosis. Apoptosis also has important implications for physiopathology. For example, a lack of apoptosis can contribute to cancerization of cells, whereas its excess in the neurones plays a part in the development of neurodegenerative diseases. Two types of approach can be used to study apoptosis: (i) study of the expression of genes/proteins involved in the regulation and execution of the apoptosis programme and (ii) study of apoptosis at the level of cell physiology, using markers such as fall in mitochondrial transmembrane potential, cytochrome c leakage, activation of caspase 3, externalization of phosphatidylserins at plasma membrane, structural alterations to DNA, etc. Many apoptosis markers—although more or less specific—are therefore available to biologists, and use of at least two is generally accepted to avoid 'false-positives'.

Markkanen et al. (*2004*) used normal yeasts and yeasts with genomes modified so as to no longer express a gene involved in the cell cycle. These latter went very easily into apoptosis under the effect of temperature, unlike their 'normal' counterparts. The GSM type radiofrequencies have no effect on apoptosis in normal and mutant yeasts. Conversely, they potentialize apoptosis induced by UV-B in the mutant yeasts, but not in normal yeasts.

Some studies have shown contradictory results in certain cells of mammals. *Marinelli et al. (2004)* have shown a reduction in the cell viability of human tumoral cells after exposure for 48 hours to a GSM-900 signal with SAR of 3.5 mW/kg. This effect appears to be linked to induction of apoptosis after 2 hours

[28] Homéostasie = tendance des organismes vivants à maintenir constants leurs paramètres biologiques face aux modofications du milieu extérieur.

of exposure. Monitoring of the expression of several genes linked to apoptosis shows a sequential expression of pro-apoptotic genes then of anti-apoptotic genes. The authors' interpretation of greater ‘aggressiveness’ of tumoral cells after exposure to radiofrequencies is not justified by the experimental results.

Conversely, *Capri et al. (2004)* did not observe pro-apoptotic effects for GSM-1800 signals (different modulation) on blood cells from young donors, even when apoptosis was chemically induced. Furthermore, *Hook et al.* (*2004*, see Chapter 3-1) did not find the effects from American mobile telephone signals on apoptosis in Molt4 human cells, observed by *Phillips et al. (1998).*

The expression of genes (and their products) under radiofrequency exposure was studied in different models.

Pursuing its work, the Leszczinski group (*Nylund et al., 2004)* showed, on the basis of a protronomic analysis,[29] overexpression of 38 proteins, from among which 2 cyto-skeleton proteins have been identified. Leszczinski's reflection on the use of protein screening techniques is of interest where the possibility of providing study hypotheses is concerned. However, caution is necessary, to avoid direct or abusive extrapolation of such results on cells to physiopathological effects in humans.

Czyz et al. (2004) have shown that, among the various signals of the GSM-1800 type, only that modulated at 27 Hz (SAR 1.5 W/kg) could induce expression of early response gene and stress genes in the embryonic stem cells deficient for gene p53, whereas the normal and P19 embryonic stem cells showed no sensitivity to exposure.

On the other hand, *Capri et al.* (2004) did not show any evidence of the effects of the GSM-1800 signal on protein Hsp70.

The work of *Yao et al. (2004)* on corneal cells of rabbits does not include a description of the exposure (exposure system, SAR) and does not therefore meet the criteria for consideration.

Desta et al. (2003), working on L929 mouse cells, did not find the increase in ODC activity under exposure to radiofrequencies reported by *Penafiel et al. (1997*)[30]. Moreover, they showed that the response to a temperature increase is a reduction in enzyme activity. A further confirmation study is under way in France and in Finland, which will probably allow for a conclusion to be drawn as to the effects of radiofrequencies on ODC enzyme activity.

Author/Review/Title	**Source/SAR/Dosimetry**	**Model/Method**	**Results**
Markkanen A, Penttinen P, Pelkonen J, Sihlvonen AP, Juutilainen J, Bioelectromagnetics, 25 :127-133 *Apoptosis induced by UV radiation is enhanced by AM RFR in mutant yeast cells*	- Source: 872 and 900 MHz, modulated or not (217 Hz), with UV-B (280−320 nm, 20 min), wave guide SAR 900 MHz: 0.4 W/kg SAR 872 MHz: 3.0 W/kg ± 35% - Exposure: 1 h - Dosimetry: calculated by FDTD and field measurement. Regulated temperature (water	**Saccharomyces Cerevisiae yeast** Cdc-48 wild-type and cdc-48 mutant, for cycline Cdc 48. Unlike the wild type, the mutant yeasts go into apoptosis when they are incubated at 37°C -Apoptosis test: annexine V affinity	- No effect of radiofrequencies alone on wild and mutant yeast. - Increased apoptosis induced by UV in mutant strains only, for levels comparable with limits of local radiofrequency exposure.

29 Leszczynski D, Joenväärä S, Reivinen J, Kuokka R. (2002) Non-thermal activation of HSP-27/P38mapk stress pathway by mobile phone radiation in human endothelial cells molecular mechanism for cancer- and blood-brain barrier-related effects. Differentiation, 70: 120-129.
30 Penafiel L. M., T. Litovitz, D. Krause, A. Desta, J. M. Mullins. “role of modulation on the effect of microwaves on ornithine decarboxylase activity in L929 cells”, Bioelectromagnetics,18(2): 132–141, 1997.

Author/Review/Title	Source/SAR/Dosimetry	Model/Method	Results
	and air) to 10 W/kg (TD = 0.3℃) - Statistical analysis: ANOVA, Tukey post hoc test.	- Apoptosis measured 12 h after UV-B ± RF	
Marinelli F, La Sala D, Ciccioti G, Cattinin L, Trimarchi C, Putti S, Zamparelli A, Giuliani L, Tomassetti G, Cinti C, J.Cell Physiol, 2004, 198 :324-332 *Exposure to 900 MHz EMF induces an imbalance between pro apoptotic and pro survival signals in T-Lymphoblastoid leukemia CCRF-CEM cells*	- Source: 900 MHz not modulated, TEM cell SAR: 3.5 mW/kg Sham exposure (in TEM) and control (out of TEM) - Exposure: 2, 4, 12, 24 and 48h - Dosimetry: method not clearly specified, measurements of E and H by spectrometer Temperature monitored by infrared measurement (TD ≤ 0.15℃) - Statistical analysis: Student test.	**Lymphoblastoid leukemia CCRF-CEM cells** - Viability test (MTT), - Apoptosis test: sub-G1 peak in cell cycle and DNA fragmentation by gel electrophoresis - Expression of pro- or anti-apoptotic genes	- Reduction in viability at 24 and 48 hours - Apoptotic cells present after 2 hours of exposure (fragmented DNA, DNA peak sub-G1) - Overexpresssion of pro-apoptotic genes bax, p53, p21 and anti-apoptotic bcl_2, ras, akt1
Capri M, Scarcella E, Bianchi E, Fumelli C , Mesirca P, Agostini C, Remondini D, Chuderer J, Kuster N, Franscheschi C, Bersani F, Int J Radiat biol, 2004, 80 : 389-397 *1800 MHz RF does not affect apoptosis and HSP 70 level in peripherical blood mononuclear cells from young and old volunteers*	- Source: GSM 1800, 3 modulations (basic; 217 Hz, 1/8 – DTX; 2.8, 217 Hz, 12/104 – Talk; Basic + DTX) IT'IS wave guide SAR: 1.4−2 W/kg - Exposure: 44 h - Dosimetry: FDTD, field and temperature measurements, monitoring of absence of hot spots and variability of SAR (20−29%). - Statistical analysis: multiple Student t test	**Peripherical blood mononuclear cells** from healthy donors Young donors (27 ± 5 years) and elderly (88 ± 1 years) Induction of apoptosis and HSP70 by 2-deoxyribose (2-dRib) - Apoptosis test: annexine V affinity and mitochondrial transmembrane potential - Expression of protein HSP70	- No effect from radiofrequencies alone, in both young and elderly populations - No potentialization of 2dRib effect, in both young and elderly populations
Czyz J, Guan K, Zeng Q, Nikolova T, Meister A, Schonborn F, Schuderer J, Kuster N, Wobus AM, Bioelectromagnetics, 2004, 25(4) :296-307 *High frequency electromagnetic fields (GSM 1800 signals) affect gene expression levels in tumour suppressor p53-deficient embryonic stem cells*	- Sources: GSM 1800 or DCS-1.71 GHz in mode: - modulated 217 Hz: SAR: 1.5 W/kg - GSM basic: SAR: 0.4 W/kg - GSM-DTX: SAR: 0.11 W/kg IT'IS cavity - Exposure: 6, 48 and 72 hours, 5 min ON/30 min OFF - Dosimetry: SAR measured and simulated (IT'IS) - Statistical analysis: Mann-Whitney test	**Pluripotent embryonic stem cells** (ESC), wild type (WT) or deficient in p53 tumour suppressor (D). P 19 carcinogenic embryonic cells - RT-PCR method - flow cytometry for cell cycle - embryonic stem test for cardiac differentiation	- ESC-D on regulation of mRNA levels for hsp70, with transient increase of c-jun, c-myc and p21 (GSM-217) - ESC-W No effect - P19 cells: no effect - No effect on cardiac differentiation
Nylund R, Leszczinski D, Proteonomics, 2004, 4:1359-65 *Proteonomics analysis of human endothelial cell*	- Sources: GSM 900 MHz, wave guide SAR= 2.4 W/kg - Exposure: 1 hour - Dosimetry method not specified	**Human endothelial cells EA.hy926** - Examination of protein status by 2D electrophoresis; mass	- Modification affecting 38 proteins - Identification of 4 proteins of which 2 are cytoskeleton proteins (2

Author/Review/Title	Source/SAR/Dosimetry	Model/Method	Results
line EA.hy926 after exposure to GSM900 radiation	- Controlled temperature Statistics: Student t tests on standardized spots	spectrometry (MALDI-MS).	vimentine isoforms)
Leszczinski D, Nylund R Joevaara S, Reivinen J, Proteonomics, 2004, 4:426-431 *Applicability of discovery science approach to determine biological effects of mobile phone radiation*	Reflection on methodology	Advantages of rapid screening of proteins (transcriptomic and proteonomic). Suggestions for strategy based on example of HSP27	
Desta AB, Owen RD, Cress LW, Radiat Res., 2003, 160(4):488-91 *Non-thermal exposure to RF energy from digital wireless phones does not affect ODC activity in L929 cells*	- Sources: TDMA 835 MHz, Crawford cell, SAR= 1 W/kg−15 W/kg - Exposure: 8 h - Temperature controlled and measured (Luxtron) - Dosimetry: calculation of SAR	**L929 murine fibroblasts** - Ornithine decarboxylase (ODC) activity	- No difference in comparison with control at non-thermal SAR levels. - Linear reduction in ODC activity with temperature. Negative replication of Penafiel et al. experiments, (1997)
Yao K, Wang KJ, Sun ZH, Tan J, Xu W, Zhu LJ, Lu DQ, Molecular Vision 2004; 10:138-43 *Low power microwave radiation inhibits the proliferation of rabbit lens epithelial cells by upregulating $P27^{Kip1}$ expression*	- Sources: 2450 MHz, exposure system not described - Exposure: 8 hours - Power densities: 0.1-0.25-0.50-1 and 2 mW/cm^2 - Temperature: exposure at 25℃ with a maximum difference of 0.6℃ between sham and exposed groups - Dosimetry: SAR not reported Absence of quality criteria for exposure	**Epithelial cells of rabbit cornea** - Cell proliferation - Protein expression	- Inhibition of cell proliferation. -Overexpression of $P27^{Kip}$ protein, involved in cell cycle.

5.4.3 Lipoperoxidation and free radicals

Production of free radicals contributes to alterations of cells and their membranes (lipoperoxidation); for example, radicals play a part in ageing.

The study by *Zmyslony et al. (2004*) suggests that radiofrequencies of the GSM type do not induce formation of free radicals, but seem to be able to increase their production once induced by $FeCl_2$.

Author/Review/Title	*Source/SAR/Dosimetry*	*Model/Method*	*Results*
Stopczyk D, Gnitecki W, Buczinski A, Markuszewski L, Buczinski J,	Source: GSM 900 MHz,	**Platelet suspensions**	- Drop in SOD activity at 1, 5, 7 minutes, with rise at 3 min

Author/Review/Title	*Source/SAR/Dosimetry*	*Model/Method*	*Results*
Prat. Med., 2002, 53(4):311-14 *Effects of EMF produced by mobile phones on the activity of SOD and the level of MDA; an vitro study*	-Exposure: 1, 3,5, 7 min *Absence of quality criteria for exposure (dosimetry)*	- Superoxide dismutase (SOD) activity - malonyl dialdehyde assay, (TBA method)	- Inverse MDA development
Zmyslony M, Politanski, P, Rajkowska E, Smymczak W, Jajte J, Bioelectromagnetics, 2004, 25 :324-328 *Acute exposure to 930 MHz CW EM radiation affects reactive oxygen species level in rat lymphocytes treated with iron ions*	Source: 930 MHz, CW, GTEM cell 5 W/m^2, SAR: 1.5 W/kg Exposure: 5−15 minutes Dosimetry: direct measurement (±10%), calculation of SAR (method not specified)	**Wistar rat lymphocytes** Assay by fluorescence of oxygenated radicals (DCF-DA) with or without oxidative stress ($FeCl_2$)	- No effect of radiofrequencies in the absence of $FeCl_2$ stimulation - Higher levels of reactive species produced in the presence of $FeCl_2$ Reference to recombination mechanisms for pairs of free radicals

5.4.4 Conclusions on cell studies

The absence of genotoxic effects of radiofrequencies at low SARs is confirmed by the most recent studies. The few studies of the process of apoptosis appear to be contradictory, but the use of very different models does not allow true comparison. For the first time, studies suggest that the genetic inheritance of cells could play a part in their response (gene expression, apoptosis) to certain radiofrequencies, but none have used human cells. Finally, it can be pointed out that the effects of low SAR radiofrequencies on ODC activity have not been confirmed.

5.5 Biophysical and mechanistic approaches

In the absence of established biological effects at low SARs, it is difficult to propose new mechanistic hypotheses and only thermal effects are considered to be known. Nevertheless, studies are in progress to gain a better understanding of field values at the microscopic level (e.g. *Munoz-San et al. 2003*) and to design *in vitro* models suitable for non-thermal effects (e.g. *Ramundo-Orlando et al. 2004*).

AUTHOR/REVIEW/TITLE	*Source/SAR/Dosimetry*	*Method*	*Results*
Munoz-San MS, Sebastien JL, Sancho M, Miranda JM, Phys Med Biol, 2003, 48(11):1649-59 *A study of field electric distribution in erythrocytes and rod shape cells from direct RF exposure*	Sources: 900 MHz and 2.45 GHz FDTD Solving of Laplace equations using finite element method. Application to intramembrane distribution to ellipsoid model, to red blood cells and rod shape cells.	The distribution of electric fields induced depends on the frequencies, electrical properties of membranes and cytoplasm and orientation in the field.	The ellipsoid cell model gives only a rough approximation of the bioeffects of radiofrequencies. An interesting approach for local effects, support to effects due to the nature (geometry) of the cell in question …
Ramundo-Orlando A, Liberti M, Mossa G, D'Inzeo G, Bioelectromagnetics, 2004, 25(5) :338-45	2.45GHz, search for a dose-effect relationship of 1.2 to 5.6 W/kg,	Ascorbate oxidase (AO) activity, estimated in Km and Vmax	Conclusion: It would be worthwhile

AUTHOR/REVIEW/TITLE	Source/SAR/Dosimetry	Method	Results
Effects of 2.45GHz microwave fields on liposomes entrapping glycoenzyme ascorbate oxydase; evidence for oligosaccharide side-chain involvement	(Earlier results from same author show effect at this SAR)	Measurement of absorbance of ascorbate. Nothing below 5.6 W/kg for AO Fordeglycosylated AO, modification of enzyme activity; No change in catalytic activity: role of glycosylated part	investigating the role of oligosaccharidic chains in the effects of microwaves on lipids

5.6 Interference with implants

Two studies motivated by concerns about possible interference between mobile telephone radiofrequencies and some prosthetic devices are worthy of note. For instance, *Grant et al. (2004)* carried out *in vitro* analysis of possible electromagnetic interactions between mobile telephones and implants such as pacemakers or other electronic prostheses, especially stimulators (Cyberonics NeuroStar (Model 102) NeuroCybernetic Prosthesis, NCP). The article is based on 1080 tests and concludes that there are no interactions. It has the advantage of detailing the experimental procedure used and, from this point of view, is of didactic value.

The same type of comparison was made by *Kainz et al. (2003),* this time with 10 types of GSM mobiles at 900 MHz and 1800 MHz, for possible effects on deep brain stimulators implanted for certain nervous disorders, e.g. Parkinson's disease. The model was studied *in vitro* on a phantom specially designed to test these stimulators (in this case the ITREL-III from Medtronic Inc., USA). Even for powers of 1 W for the 1800 MHz sets and 2 W for the 900 MHz, no influence was detected on the ITREL-III stimulator. These investigations did not therefore indicate any risk to patients fitted with an ITREL III and using a GSM under normal conditions. The test was continued placing a dipole emitting at constant frequency next to the ITREL; this seemed to produce a positive effect. The recommendations are the same as for heart pacemakers: to use the ear opposite the implant side and to avoid wearing the telephone near to the implant.

5.7 Children: specific aspects (dosimetry, biological effects)

Several recent documents have entertained the possibility of a particular susceptibility of children to exposure to radiofrequency fields (*Van Rongen et al. 2004 ; SSI, 2004 ; Lin, 2004*). In June 2004, the WHO convened a meeting of a working group, in Istanbul, Turkey, to assess the available information on susceptibility of children to radiofrequency fields and to identify priority lines of research. This chapter is based on all of those documents.

Children in both industrialized and developing countries are exposed to a wide range of chemical, physical and biological agents present in the environment. Such environmental exposure can be particularly harmful to children because of their increased susceptibility during their development and the possibility of irreversible effects on their health. With the development of technologies using radiofrequency fields, and in particular of mobile and cordless telephones, the number of radiofrequency sources has increased considerably. Uptake of these technologies by children at increasingly young ages has raised the question of a particular risk to children.

The development of the organism is different in embryos, babies, children and adolescents. Development in the prenatal period is characterized by highly ordered sequences of cell proliferation and differentiation, migration and programmed cell death (apoptosis). It comprises three main stages: pre-implantation (from fertilization to implantation of the embryo in the wall of the uterus); an organogenic period; and the fœtal period during which the different structures develop. The developing nervous system seems to be especially vulnerable, given the limited number and distribution of sites of the proliferating cells which are at its origin. After birth, the development of most of the tissues and organs is completed by full sexual maturity, between 20 and 30 years of age. Development of the central nervous system continues throughout childhood and adolescence, with the processes of myelinization and synaptogenesis.

During the embryonic and fœtal stages of development, exposure to toxic substances can lead to death, congenital malformation, retarded growth of the foetus or of organs, mental handicap, microencephaly, neuro-behavioural disruption or premature birth. In the post-natal stages of development for babies, children and adolescents such exposure can retard growth or cause cancers, interfere with fertility or development of the immune system or alter neurological development, etc. (*Rodier, 2004*).

To date, few agents present in the environment have been assessed for their effects on children. Increased susceptibility to certain toxic substances (lead) or physical agents (ionizing radiation) has been shown in children. In certain cases, this susceptibility could imply more numerous cell divisions in developing tissues or organs, but the mechanisms for such increased susceptibility are not known. In addition, cases of increased resistance have also been described.

The number of adolescents having mobile telephones is increasing rapidly, and it is reported that younger and younger children are concerned. When they reach adulthood, today's children will have undergone a longer period of exposure to radiofrequencies than present-day adults, although technological developments are bringing about forms of use of mobile telephones that are tending to move the telephone away from the head (see Chapter 4).

In the case of mobile telephones, the question is whether or not there is a difference in absorption of radiofrequencies by the heads of children and adults. There are numerous anatomical and physiological differences that can influence such absorption. Dosimetric modelling of radiofrequency exposure must therefore take account of the differences in size and morphology of the head, thickness of the skull and dielectric properties of tissues.

Modelling of SAR in models of children's heads based on a homogeneous reduction, or not, of the models of adult heads is unsuitable (*Anderson, 2003*). Only MRI imaging, which will take account of the variations relating to age and differences between children, will allow improvement of the models of children's heads. However, it appears that at present, in spite of the large differences in size, form and distribution of tissues in children's heads, SAR values are very similar to those for adults. The relative depth of penetration is however higher for children, given the smaller size of the head (*Martinez-Burdalo M, 2004*).

Evaluation of a potential role of environmental exposure in the development of illnesses in children must also take account of exposure during pregnancy and exposure of the mother. For mobile telephones, use of hands-free kits risks bringing the telephone closer to the abdomen. Initial estimates indicate that, in this case, exposure of the foetus is very low (*Kainz et al. 2003*). The models currently being developed should provide even better resolution.

Where biological data are concerned, the only clearly identified mechanism is that linked to heating of the tissues during exposure to high energy levels. The mechanisms that could lead to effects at low levels of exposure are not known at present.

The studies relevant to the assessment of a potentially greater susceptibility on the part of children to radiofrequency exposure are reviewed below. These studies are of cancer, the immune system, development, behaviour and cognitive functions.

Cancer and the immune system

Only a few studies have used exposure of prenatal or newborn rodents. *Adey et al. (1999)*[31] exposed pregnant rats to American mobile telephone signals. No effects were observed on the appearance of spontaneous tumours of the central nervous system (CNS) in the litters of exposed rats. Moreover, the authors noted a tendency towards reduced incidence of CNS tumours in rats treated *in utero* with the chemical carcinogen ENU[32].

Other studies were of animals aged 5 or 6 weeks and sexually mature (to be compared with adolescent or young adults) at the start of exposure, which lasted two years, almost their entire lifespan. The processes of initiation and promotion were studied. All of the studies of this type have given negative results in normal animals exposed to SAR levels compatible with mobile telephony (see Chapter 5; *Heikkinen et al. 2001*[33]*; Zook et al. 2001*[34]*; Bartch et al. 2002*[35]). The work indicating an increase in incidence of tumours in mice pre-disposed to develop lymphoma and exposed to radiofrequencies (*Repacholi et al. 1997*[36]), was not confirmed subsequently (*Utteridge et al., 2002*[37]*).*

To our knowledge, only the negative study by *Gatta et al. (2003),* has looked at the effects of radiofrequencies from mobile telephones on the immune system (see Chapter 5). It is generally accepted that the agents that disrupt the immune systems in adults do not alter the immune systems of children. It would be necessary to carry out the appropriate studies to verify this.

Development

The numerous studies that have assessed the effects of radiofrequency fields in mammals, birds and other species have shown unequivocally that radiofrequencies are tetrageneous at levels high enough to cause a significant temperature increase (*review by Heynick and Merritt 2003*).

Regarding the process of differentiation, which plays a major role in the development of organisms, only the study by *Czyz et al. (2004)* has shown a different response for stem cells of mice that were normal or deficient in the tumour suppressing gene p53 (Chapter 5).

[31] Adey WR, Byus CV, Cain CD, Higgins RJ, Jones RA, Kean CJ, Kuster N, MacMurray A, Stagg RB, Zimmerman G, Phillips JL, Haggren W. (1999) Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats chronically exposed to 836 MHz modulated microwaves. Radiat Res 152:293-302

[32] ENU: ethylnitrosourea

[33] Heikkinen P, Kosma VM, Hongisto T, Huuskonen H, Hyysalo P, Komulainen H, Kumlin T, Lahtinen T, Lang S, Puranen L, Juutilainen J. (2001) Effects of mobile phone radiation on X-ray-induced tumorigenesis in mice. Radiat Res 156:775-85

[34] Zook BC, Simmens SJ. (2001) The effects of 860 MHz radiofrequency radiation on the induction or promotion of brain tumors and other neoplasms in rats. Radiat Res 155:572-83

[35] Bartsch H, Bartsch C, Seebald E, Deerberg F, Dietz K, Vollrath L, Mecke D. (2002) Chronic exposure to a GSM-like signal (mobile phone) does not stimulate the development of DMBA-induced mammary tumors in rats: results of three consecutive studies. Radiat Res 157:183-90

[36] Repacholi MH, Basten A, Gebski V, Noonan D, Finnie J, Harris AW. (1997) Lymphomas in Eμ-Pim1 transgenic mice exposed to pulsed 900 MHZ electromagnetic fields. Radiat Res 147:631-40

[37] Utteridge TD, Gebski V, Finnie JW, Vernon-Roberts B, Kuchel TR. (2002) Long-Term Exposure Of Eμ-Pim1 Transgenic Mice To 898.4 Mhz Microwaves Does Not Increase Lymphoma Incidence. Radiation Research 158, 357–64.

Behaviour and cognitive functions

Available studies on the effects of radiofrequencies from mobile telephones on cognitive functions (attention, memory, etc.), sleep or electrical brain activity were carried out on adults. Some of them are presented in this report (Chapter 5) and, overall, no reproducible response was shown after short-duration exposures. Extrapolation of these results to children is possible, but no one can guarantee the validity for assessment of the associated risk. It will be necessary to wait for the results from groups testing the cognitive functions, the EEG and an occurrence of subjective symptoms in adolescents exposed to radiofrequencies.

The possible effects of radiofrequencies on animals was studied using approximating methods, from the search for expression of specific genes and the activity of neurotransmitters to behavioural studies. Most of the effects of exposure to radiofrequencies were linked to hyperthermal effects or to different types of stress associated with exposure (immobilization in particular). The case of the work of Lai, reporting altered behaviour in rats exposed to pulsed radiofrequencies, has been discussed in this report (Chapter 5). The existence of contradictory studies can also be mentioned here, on the effects of radiofrequencies with low SARs on the haematoencephalic barrier. Additional studies are needed to assess the risk of neurodegenerative diseases linked to the use of mobile telephones.

Conclusions

All of the data presented highlight the lack of knowledge at the present time of a possibly greater susceptibility on the part of children to radiofrequencies, and also to numerous other environmental factors.

The absence of major deleterious effects in animals or adult humans is an imperfect indicator of what may happen for the newly-born or for the young. For example, the embryonic stage is marked by increased differentiation not found in adults. In the absence of studies assessing the responses of animals exposed *in utero* or throughout the first part of their lives, nothing allows us to discount the possibility of the existence of deleterious effects for children that do not exist for adults nor, conversely, of a greater capacity for recovery in children. It therefore appears necessary to design and carry out experimental studies providing direct and usable data on the existence of a particular susceptibility to exposure to radiofrequencies in children.

5.8 Conclusion on mobile terminals

The appearance of a study indicating a possibly increased risk of vestibular-acoustic neurinoma after prolonged use of the mobile telephone, and the Danish study—negative for an excess incidence of neurinoma but seeming to indicate an increase in size of tumours on the side on which the telephone is used—support the doubts raised by earlier studies. The possible physiopathological mechanisms are not yet evident. On the other hand, there are no new elements regarding the types of tumours of the head. The relatively unsophisticated statistical analyses resulting from the still low numbers studied do not allow in-depth examination of the cause-effect relationship. It therefore remains necessary to await the results of the Interphone project. This international study will not, however, answer the question of possible increased susceptibility in children.

Conversely, it seems proven that the use of telephones in certain conditions (long distance calls, high powers) can, in certain subjects, cause localized symptoms relating to heating due to the battery, which was highlighted in the previous expert study. Regarding the other types of pathologies, especially neurological, no new study provides any elements of a possible effect

Finally, while the risk of accident is perhaps lower than that measured in the first studies, it persists even when using hands-free kits.

Regarding experimental studies on humans, it is evident that a large number of investigations are seriously lacking in precise dosimetric data. It should be noted that some results indicate an effect favouring performance. Some other explorations report alterations to markers (especially electro-physical) whereas behavioural tests remain normal, suggesting that either the behavioural tests are not sensitive enough or there is no precise relationship with the markers. Recent publications show that, in the absence of heating, there is no proof of the existence of proven harmful effects on human health.

The results of animal or cell studies obtained at low levels raise few new questions: the existence of effects at low level during gestation cannot be discounted and research in this direction should be pursued; studies of co-promotion of tumours in the presence of identified carcinogens does not show effects of exposure on tumour development. In the case of DMBA, the association with radiofrequencies at relatively low levels calls for more investigations, especially into the possible mechanisms of co-promotion by the radiofrequencies. The absence of genotoxic effects of radiofrequencies at low SAR is confirmed by the most recent studies. The few studies on the process of apoptosis seem contradictory, but cannot be compared because of the use of very different models. For the first time, studies suggest that the genetic inheritance of cells could play a role in their response (gene expression, apoptosis) to certain radiofrequencies, but none have used human cells.

6 BIOLOGICAL AND HEALTH EFFECTS OF BASE STATIONS

6.1 Epidemiology

6.1.1 Report on St-Cyr-l'Ecole

The investigation carried out in the French town of Saint-Cyr-l'Ecole is a descriptive epidemiological study. The study, responding to a health signal from the local authorities and local associations, had two goals; to:

- assess the existence of a cluster of cancers among children (0−14 years) within the municipality of Saint-Cyr-l'Ecole between 1990 and 2002;
- identify a possible environmental source or origin.

Eleven cases of cancer were recorded amongst children of 0 to 14 living in Saint-Cyr-l'Ecole at the time of diagnosis and during a study period from 1 January 1990 to 31 December 2002 (when the expected number of cases from records was 5 or 6). In particular, five cancers of the CNS were found, whereas the expected incidence of this type of cancer was 1,2 (i.e. one to two cases).

However, given the heterogeneous nature of the types of cancers, and in view of the environmental results, the Institut National de Veille Sanitaire (national health monitoring institute) concluded that this distribution could 'correspond to the usual fluctuation around the mean without reflecting an abnormal situation'.

The study was purely descriptive in nature, looking for a cluster of pathologies, and not an analytical study attempting to analyze a possible link between the pathologies and the presence of base stations. In fact, the InVS considered, based on the opinion of international expert committees, that proximity of base stations did not present any health risk, given the very low levels of exposure of the population to the electromagnetic fields emitted by these relays and the absence of any scientific elements indicating the existence of a risk at these low levels.

On the other hand, as part of the investigation of potential sources of environmental nuisance, the InVS conducted several investigations allowing it to localize all of the sources of radio transmission electromagnetic fields within the municipal areas of St-Cyr-l'Ecole. This work did not indicate a cluster of cases around the base stations or radio installations in the municipality.

The study did not consider symptoms and pathologies reported by some inhabitants of the Epi d'Or district in the (non-representative) survey conducted by a group of associations: the symptoms and pathologies in adults covered a wide range and were unconnected. The symptoms were somewhat vague and fell within the most common complaints found in a given population. Some of them could be reactions to stress.

6.1.2 Epidemiological work

A limited amount of work[38] can be cited here, addressing the possible effects of exposure to base stations. One example is the second publication on the survey carried out by Santini (*Santini, 2003*) on the health of people living close to such installations, the first results of which were reported in an article in 2002. This new publication analyzes the effect of the age of subjects, duration of exposure and their position in relation to electromagnetic sources. The survey of 530 subjects was conducted by questionnaire. The questionnaire addressed subjective symptoms amongst people surveyed who used a mobile telephone for more than 20 minutes per day. These subjects complained of difficulties in sleeping, headaches and fatigue. Other factors were covered in the analysis, such as proximity of television transmitters. The author compares the symptoms among subjects in terms of the distance of their homes from base station antennas. He concludes that it is dangerous to remain within 300 metres of a relay station. It must be pointed out that a major bias in the selection of the population for this study prevents the author's conclusions from being taken into account. The development of a stress-related pathology due to a fear of the antenna which is present and above all visible cannot be discounted in every case. Two studies of cancer clusters, by clinicians in Germany and Israel, have been published in local reviews not noted by the international scientific community. These studies suffer from important methodological bias, especially in their definition of study populations, and they cannot be taken into account (*Eger et al., 2004*)(*Wolf R and Wolf D, 2004*). Unfortunately, despite the criticism of these assessments, they are still frequently quoted and carry some influence. Given the increasing numbers of antennas, such effects, if they were to be proven, would have resulted in an increase in appointments with doctors on a scale that could not be overlooked by those involved in health care.

38 It is quite normal to find only a few studies of this type given that the different official bodies or expert groups decided not to undertake this type of study before the results of studies of the equipment itself, considering that the levels of exposure were much lower for populations exposed to base stations than for mobile telephone users, and in the absence of the possibility of individual measurement of subjects exposed.

6.1.3 Work in progress

A study is being developed in Great Britain to examine the incidence of cancers in children around mobile telephone base stations. This a case-control type study, set up and directed by Eliott.

6.2 The TNO study

6.2.1 Summary of the TNO study [39]

In a Dutch study, made public in September 2003, volunteers were exposed briefly to waves similar to those emitted by base stations: the COgnitive Functions And Mobiles (COFAM) study (*Swamborn et al., 2003*). These experiments were carried out in a well-respected research laboratory, TNO (Physics and Electronics Laboratory), which has described the results at conferences, but has not yet published them in a scientific journal.

Two groups of subjects were set up for the purposes of this study: Group A, selected from a register of subjects declaring themselves to be sensitive to the effects of mobile telephone antennas, and Group B, selected from people who were not affected when close to an antenna. The age and gender structures of the groups is very different, a difference linked to the difficulties in recruiting subjects.

The initial objective of the study was to test the cognitive functions with a Taskomat test, testing reaction times, memory comparison, visual selective attention and dual tasking. The second objective was to also test the subjective notion of well-being, defined in terms of a score from a standardized questionnaire. Two questionnaires were used at the end of each exposure session: the Big-Five questionnaire and the Well-Being questionnaire. The Big-Five questionnaire gave insight into psychological aspects such as neuroticism, extroversion, openness, agreeableness and conscientiousness. The Well-Being questionnaire gave quantitative scores from 0 to 3 for different types of symptoms: anxiety, somatic, depressive, inadequacy, hostility. The score was established for each type of symptom and the authors then summed the scores to obtain an overall score for well-being or quality of life.

This was a fairly restricted pilot study showing that low amplitude effects were observed under exposure, especially for non-sensitive subjects, particularly for the well-being parameters and above all with the third-generation UMTS signal, rather than the GSM 900 and 1800 signals. The authors' conclusion is that UMTS signals had an adverse effect on well-being for both groups.

6.2.2 Criticisms of the TNO study[40]

This study has been criticized from the point of view of methodology (statistical analysis, operating mode of emitters, use of well-being questionnaire, etc.) but it nevertheless constitutes a reference that is in the process of being replicated (*Achermann, Kuster et al.,* financed by the Swiss mobile telephony foundation).

The EMF committee of the Dutch ‘Health Council’ recently (June 2004) issued its conclusion on the TNO study to the Ministry of Health.

39 **TNO Physics and Electronics Laboratory. Effects of Global Communication system radio frequency fields on Well Being and Cognitive functions of human subjects with and without subjective complaints**. Report September 2003

40 Knottnerus et coll Health Council of the Netherlands : TNO study on the effects of GSM and UMTS signals on well-being and cognition. Review and recommendations for further research. Report June 2004

On the basis of replies provided by the TNO study's authors to the EMF committee, the committee concluded that the study had been well designed and carried out but that some comments could be made on the interpretation of results.

The GSM 900 and 1800 signals did not affect well-being in the two volunteer groups, whereas the UMTS signal caused an increased index corresponding to a (slight) adverse effect on both groups, but at a field level rarely encountered in the public's daily environment.

After the debate as to the validity of the questionnaire used, the committee recommended that its validity be verified by two distinct experiments.

Where cognitive functions are concerned, the in-depth statistical analysis showed that it was only for the ‘non-sensitive’ Group B that an effect (greater speed of response) appeared in the comparative memory tests, with exposure to the UMTS signal. On the basis of this result, the committee did not conclude that there was a health effect.

The committee therefore strongly recommended replication of this study, advising: (i) keeping the mode of exposure as close as possible to that of the initial study (ii) increasing the number of volunteers per group (iii) asking volunteers if they perceived the field, and (iv) using the same questionnaire while validating by separate studies.

The committee also recommended other complementary studies on the possible effects of UMTS signals. The following points appear to be particularly important: (i) is it possible to be objective about particular sensitivity on the part of certain people? (ii) is there a dose-effect relationship between exposure and effect that is a function of intensity, duration and modulation of signals?

The committee's final conclusion is that a reduction in well-being is not necessarily associated with a health effect and therefore with measures to reduce exposure to UMTS signals.

6.2.3 Opinion of the expert group

After publication of this article on the TNO study, the expert group recognized the initial quality of the experiment plan (different groups, random order of exposure, number of subjects) but raised questions about several aspects of the study and therefore of the replication in progress. In fact, a replication study is only really relevant if it avoids the errors in methodology. These are relatively serious and require a reconsideration of the study methodology.

For example, it is unfortunate that the experiment plan was not complete, so as to obtain a symmetrical plan (all pairs only received two exposures out of three, to which the training and placebo tests must be added), even if the number of psychomotor tests was reduced to remain within acceptable experiment periods.

It would have been interesting to know the type of information given to subjects in the reference group in order to participate in the study (could this group have been biased by the type of information given?). Moreover, exclusion criteria No. 6 for the two study groups (i.e. ‘any other condition that may interfere with the study, according to the opinion of the investigator’) is once again too imprecise to ensure that there is no bias.

The experiments were carried out with test signals only and without real communications traffic, which is unrealistic.

The results of the cognitive function tests are, to say the least, disparate and inconsistent and do not allow for an overall direction to be established, as the few significant results tend to point to improved cognitive functions.

The well-being questionnaire aimed to test various aspects of this notion of 'well-being' and to provide an overall comparison on the basis of summed scores for these different aspects. The question can be raised as to the validity of such summed scores which are, by their nature, subjective. Conversely, the study gives no results for the tingling sensations, headaches or nausea often reported.

The conditions of use of the two well-being tests do not appear to have been strictly in compliance with the validated conditions of use, especially regarding the fact that the two tests were used successively four times in the same day, at 45-minute intervals, which does not comply with the rules of use of such subjective tests, which are supposed to be evaluated over a period of six weeks.

Summing of the test scores does not seem fully justified. In addition, this test was not subject to any serious validation of its use in the context of the TNO study, as it was constructed as a sub-part of a questionnaire for pharmacological tests relating to the treatment of depression.

Two aspects should have been evaluated before the study: (i) does use of only one sub-part of the initial test effectively measure subjects' well-being over a limited period of time [i.e. the experiment period] (sensitivity and specific aspects of this sub-part, existence of a threshold etc.)?; (ii) switch from a test designed in paper form to computer screen (the testing of ten subjects prior to analysis is not sufficiently well explained to ensure that this provided a good assessment of this manner of conducting a test). The fact that no significant difference was found for a small number of examples does not, of itself, constitute validation of conducting the test on screen.

Predictably, a significant difference is observed between groups A and B, arising from their different structures. A significant difference is also observed between the placebo and UMTS exposure in both groups, but only for summed scores. Where scores for each type of symptom are concerned, the results diverge with an effect for somatic symptoms, hostility and anxiety in Group A only; feelings of inadequacy were significantly altered in both groups, and signs of depression in neither. This test leads to a positive result only if a comparison is made of the extroversion aspect in both groups A and B which, of course, is meaningless as the structures of the two groups are very different, as were their modes of recruitment (large majority of women in Group A and of men in Group B). Such a result was more than predictable and does not, in any way, make it possible (as some have done too hastily) to conclude that there is a difference between certain 'hypersensitive' people and others. The authors themselves stress the fact that no useful comparison can be made between the groups.

Furthermore, it would have been important to have the rules for elimination of aberrational values.

Finally, in the first report, the authors only present two-by-two analyzes, with non-parametric tests, equivalent to not taking account of the experiment plan (the tests in this procedure are considered as being independent, which is not the case); it is only later that more in-depth statistical analysis (statistical analysis of variance by ANOVA) of the general model, to evaluate combinations, and by MANOVA, allowed consideration of the factors of age and gender that come into play in psychomotor tests (remembering that these two factors were not evenly distributed between the two groups whereas they play an important part in test responses). After these latest analyzes, there only remains an effect in Group B, for one test (memory comparison) and one signal (UMTS). This type of test is, in principle, less subjective than the well-being assessment, but the effect appears 'slight'.

It would have been desirable for the results to be presented not only with their statistical test p value but also with standard deviation or confidence interval.

6.2.4 Conclusions on the TNO study

Analysis of the methodology of the study and its results shows that it would be necessary, to avoid criticism and obtain usable results, to refine the design of the study and control the different experiment phases.

The expert group is of the opinion that it is not desirable to carry out other replication studies in France while awaiting the results of the Swiss[41] study and the English study (Elaine Fox) due to start.[42]

6.3 Studies on animals

All of the studies on animals described above that were carried out with whole body exposure are, *a priori,* relevant for assessment of health effects due to exposure to base stations, even if the SARs used in the studies are around 10 000 times higher than environmental levels. This is also true for *in vitro* studies.

6.4 CSO sociological study

An interesting sociological study has been carried out by the Centre de Sociologie des Organizations (CSO − centre for sociology of organizations) under a research contract with telephone operators on the topic of 'controversy and actions around mobile telephone relay antennas'. After a first chapter, in which the authors analyze the different contexts for players concerned by the development of mobile telephony (manufacturers, international organizations including the WHO, French regulatory bodies, the operators and their approach to deployment, and nearby residents), they provide a more specific analysis of the confrontation between two opposing attitudes (on the one hand, the public authorities and operators who tend, according to the authors, to think that the risk from mobile telephones is small and that from antennas is zero) and on the other hand, a variety of interest groups, supported by opposing experts, who think that mobiles and their antennas are a danger to health. In the final part, the researchers show that these opposing groups have adopted parallel strategies, even to the point of mimicking one another, to get their point across.

In their conclusions, the authors recall the questions they posed before the study, as to why reaction to deployment of antennas was so late in coming, why it was so virulent, and why it focused on antennas when the doubt is about terminals. They then put forward several arguments from their work:

- The movement is a reaction to an incursion into territorial environments in which populations live. The failure on the part of public authorities or the industry to understand this intrusion—an antenna being something benign and commonplace to them—creates a feeling of lack of recognition and disdain. The movement has therefore grown in autonomy and 'remains consubstantial with the existence of unanswered questions'. In this context, 'virulence and hostility' become the fuel for the dynamism of the movement: 'it is wholly unacceptable to see that a place where people live, and their health, depend on players who appear to be irresponsible'.

41 www.mobile-research.ethz.ch/english/projekte_e.htm#18
42 University of Sussex : www.mthr.org.uk/research_projects/hypersensitivitysymptoms.htm

- The difficulty for the public authorities in responding at this (too late) stage lies in the fact that the movement is ‘decentralized and proteiform, continually changing’, and outperforms the State's much heavier, tiered structures.

In summary, it is the disruption of localities combined with the failure to accept discussion on the part of those responsible for regulation of civic space that ‘underpins the foundations of the movement, and not directly the effects, real or potential, of the waves emitted by terminals or antennas.’ The movement is, basically, independent of telephony itself, but its objectives relate to the ‘life space’. This deficiency will persist so long as a process of consultation is not initiated. In this context, local charters provide a means and the rules to end confrontation. ‘Their spread reflects a growing awareness on the part of local representatives of the necessity for political action’. Finally, the authors insist on the fact that ‘in the absence of a context that allows a learning process based on objective data, it is not possible to go from a situation in which perception predominates to one in which a cognitive and political operation will allow even the uninitiated to assess the risk, perception alone being particularly strong where only mechanisms of uncertainty and anxiety that have not been addressed are involved, and which are reinforced every time a movement leads to the removal of an antenna. A concrete action that wins out in this way allows the players to ‘feel that their ‘elective’ identity is recognized.’

These conclusions are interesting, all the more so because they bear out observations already made of other environmental conflicts (especially those involving waste).

The preamble to the report merits further consideration, in that the sociologists stress the difficulty (and even the impossibility) they experienced in meeting certain players. They highlight the questioning of their motives because their study was conducted at the request of the operators (who financed it). It should be noted that this kind of suspicion, generally unfounded, is likely to increase in coming years, as research will increasingly have to look to non-public financing, public financing becoming rarer and more difficult to obtain. This aspect, which is one of the areas currently under consideration by the research community, should be brought to the notice of civil society in France and be a subject of debate, so that whatever political choices are made where research is concerned, its financing will be governed by rules that are explicit and transparent, to avoid researchers being systematically suspected of being in the pay of industry.

6.5 Conclusions on base stations

In the absence of studies with rigorous methodology into the relationship between base stations and health effects, there are no new scientific elements to affirm the existence of any such relationship. No new element therefore justifies any re-examination of the previous report.

7 BIOLOGICAL EFFECTS OF NEW SIGNALS

7.1 UMTS

After numerous studies with GSM-type signals and with current deployment of UMTS, questions are rightly asked as to the specific nature of possible health effects depending on the nature of the signal.

The question of extrapolating GSM results to UMTS has been mentioned or discussed at numerous conferences.

The differences between the two types of signal were explained above.

Where the carrier frequency is concerned, it is certain that the depth of penetration of the field will reduce when the signal goes from 900 to 1800 MHz (GSM) then to 2000 MHz (UMTS). This is the only parameter that could have any influence, especially regarding the absorption by different tissues (skin, brain, etc.), but no particular influence of frequency is envisaged, as this is still in the absorption band for water which has its maximum at around 18 GHz.

The maximum power of UMTS terminals will be very close to that of the GSM-1800 and SAR in the head will be similar. On the other hand, as power control will be more efficient in the case of the UMTS, the effective SAR will probably be much less than for the GSM.

Finally, the UMTS signal is, *a priori,* less recurrent than that of the GSM, which is modulated at 217 Hz and, if modulation is the cause of biological or health effects, the UMTS will, from this point of view, be a 'better' signal. However, it should be borne in mind that, to date, there is no proof that low frequency modulation is the source of biological effects.

7.2 Wi-Fi

Wireless local networks have developed in parallel with mobile telephone systems. In particular, those using protocols grouped under the name Wi-Fi have spread widely, thanks to the installation of 'hotspots' in public places where the Internet has become accessible from laptop computers equipped with a radio card. These are local networks consisting of a central base connected to the network and to users within a radius of around 100 metres. The carrier frequency used at present is 2450 MHz and the power around 100 mW.

Wi-Fi exposure is always far-field (at least 50 cm) and emission power is low. Comparison with published limits shows that the usual levels remain well below limit values. This has been confirmed by measurements made in real environments, including with numerous sources in a single room.

The present carrier frequency is that used for most of the previous mobile telephone studies. Extensive knowledge exists of the biological effects of exposure to this frequency. The results obtained at low level have, globally, been negative, and it is unlikely that conditions of use of Wi-Fi will be the source of particular problems (given duration and level of exposure).

8 OTHER EFFECTS

8.1 Use of the mobile telephone and social changes

An important French study (*F. Jauréguiberry 2003*) has been published on the sociology of use of the mobile telephone, of which some elements are presented below.

The mobile relates to a permanent need for reassurance ('telephone cocooning', and its rider: the stress induced when someone is out of contact), resulting in a compulsive attitude the author calls 'telephonitis'. The mobile allows connection to social networks. Its use masks a desire to control time, whereas, for the author, this time control has perverse effects: 'a general sense of urgency' which, obliging subjects to make decisions on the spur of the moment, actually leads them to put off making decisions rather than to anticipate them. However, the instinct for self-preservation appears when subjects disconnect, to allow themselves periods of unavailability. The author describes a 'trilogy': Zapping (going rapidly from one item of information to another), Filtering (to provide rest periods of unavailability), and Preservation (restricting the mobile to a strict minimum to return to the authentic nature of face-to-face conversation).

The mobile allows users to be elsewhere and to broadcast (or show) it. Calling from a public place is not a neutral action: the mobile represents a break with civility. In occupational surroundings, a mobile user will go un-noticed, in more social surroundings (restaurant, cinema), he or she will be seen as an intruder.

Finally, in professional situations the mobile is creating new forms of inequality (experienced at work) and is leading to increased control, to the detriment of autonomy (sales people): piling of problems onto managers leads to increased pressure on those who constitute the 'fusible links' in the management chain.

Other studies have concentrated specifically on the relationship of adolescents to their mobiles (*Wilska, 2003; Davie, 2004*). The freedom that the mobile gives to adolescents is the most common element: complete control over their contacts—'I can call who I want, when I want and where I want', without parental control. Wilska returns to the same idea as the author mentioned above: addictive behaviour where mobiles are concerned.

Other authors point out that a significant proportion (7 to 17 per cent) of children receive (or have received) messages that they perceive as threatening. Finally, the study by Davie indicates that 20 per cent of children attending primary school who use mobiles have been attacked so that telephone can be stolen.

8.2 Beneficial effects

It seems important within the framework of this report to underline the beneficial health effects of these new radio systems. The reality of more rapid intervention by the relevant services in emergency situations hardly needs mentioning again. Similarly, we can cite the reassurance that provision of a telephone has provided to certain people in particular circumstances.

Use of radio communications is developing in the area of telemedicine (*Hung, 2003; Keeling, 2003*; *Tachakra, 2003*), allowing a patient's medical data to be provided rapidly or emergency life-saving procedures to be guided at a distance. Such systems are useful for the long-range monitoring of high-risk patients (*Kosaka, 2003; Durso, 2003*), carrying out of epidemiological studies or providing health care (*Collins, 2003*; *Wilkins, 2003; Lehalle, 2003; Vitella, 2004*). *Campbell and Durigon* (*2003*) have shown the particular advantages of three systems (Wi-Fi, Mobile Communications & Bluetooth) for such interventions and for remote monitoring.

The problem of use of telephones in hospitals remains to be solved. They can be of great use to personnel, patients and families while, at the same time, being a potential source of interference with medical equipment (*Omer, 2003*).

9 REGULATIONS AND IMPLEMENTATION

French regulation limiting exposure of the public to electromagnetic fields is in compliance with the European framework, especially with European recommendation 1999/519/EC of 12 July 1999 and

Directive 1999/05/EC of 9 March 1999, known as the ‘R&TTE’ directive. It covers both radioelectrical terminals and stations.

The limit values for electromagnetic fields emitted by radioelectrical stations and radioelectrical terminal equipment result, respectively, from Decree No. 2002-775 of 3 May 2002 and the Order of 8 October 2003 giving the technical specifications applicable to radioelectrical terminals. The Circular of 16 October 2001, which defined the safety perimeter around mobile telephone relay antennas, should soon be complete for the other categories of radioelectrical stations.

Compliance with limits is verified by the ANFR when agreements are signed for installation of radioelectrical stations covered by the COMSIS procedure of Articles L 43 and R 52-2-1 5 of the Post and Electronic Communications Code.

Moreover, Article L 34-9-1, item 2 of the same code (Law 2004-669 of 9 July 2004) provides for verification of compliance with these limits, on site by qualified bodies applying the measurement protocol established by the ANFR and for which the references were published in the *Official Journal*, under an Order of 3 November 2003. These bodies will, in the long run (under a text as yet unpublished), have to meet quality criteria defined by Decree, in particular having to be accredited by the *Comité français d'accréditation* (COFRAC − French accreditation committee) or by an equivalent European body, in order to guarantee the reliability of measurements made of electromagnetic fields. The corresponding text is being drafted, but some technical monitoring bodies have already undertaken the necessary steps for accreditation. Failure to comply with limit values will constitute a penal offence punishable by a fine for offences of the fifth class, in accordance with Article R 20-25 of the Code.

Law no. 2004-806 of 9 August 2004 introduced requirements into the public health and post and electronic communications codes that supplement the legal provisions for protection of the public against exposure to electromagnetic fields, so as to foster wider collaboration with stakeholders. Article 1333-21 of the Public Health Code gives the Prefect the power to require measurement of electromagnetic fields, at operators' expense, under the conditions stipulated by an interministerial order (not signed at the time of writing). Article L 96-1 of the Post and Electronic Communications Code allows mayors to demand that operators of radioelectrical installations provide an inventory of radioelectrical installations in their municipality. The contents and procedures for transmission of this dossier will be stipulated in another interministerial order. Publication of the texts specifying the procedures for application of these new conditions is pending.

10 INTERNATIONAL ACTIVITY

10.1 WHO

The World Health Organization's international “EMF” programme has been in existence since 1996. Its website describes the entire range of its activities in detail.[43] Meetings of the three support organizations

43 www.who.int/peh-emf/fr/index.html

are held annually (i.e. IAC – International Advisory Committee; RRC – Research Coordination Committee and Standards Harmonization Committee; and National Reports).

The major activities of the “electromagnetic fields” unit of the WHO, which implements the EMF programme, are to assist with the coordination of research (cf. research programme in the appendix), the harmonization of exposure limits and risk communication. These roles are carried out in close cooperation with organizations such as the ICNIRP, EMF-Net and others.

10.2 European programmes

10.2.1 Perform A B C

Three major studies have been conducted within the framework of the Perform A research programme: 1) two long-term bioassay studies in rats and mice exposed to mobile phone signals, 2) a replication of the Repacholi study of 1997 showing an increase in lymphomas in transgenic mice, and 3) a study on the incidence of chemically induced mammary tumours in rats exposed to the GSM 1800 signal.

These three studies, conducted respectively in Germany, Italy and Austria, were financed in part through the 5th RDFP. They have now been completed and are in the final stage of histological and statistical analysis. The full results will be known in several months.

The Perform B European programme has just been completed after two and a half years of research involving “*in vitro* and *in vivo* replication studies relating to adverse health effects from mobile telephony”. The PIOM laboratory in Bordeaux coordinated this programme. Two laboratories worked side by side on each of the three topics dealt with (genotoxicity, the action of ODC[44] and rodent memory). Several exposure systems were constructed or adapted for these studies.

On the basis of the results of Maes in Belgium, studies have been conducted on the impact of RF fields associated with ionizing X-rays. Several *in vitro* genotoxicity tests were used, and the exposure was produced via GSM 900 (1 and 2 W/kg) and 1800 signals (1 W/kg). No genotoxic effect was observed.

Following the Litovitz group's research on the action of ODC in L929 cells, research conducted with various RF signals on several types of cells did not confirm the Litovitz results. The action of ODC was not modified by the exposure.

The Lai group in the United States had published results showing an alteration of learning in rats exposed to pulsed RF signals. The studies conducted as a part of the Perform B programme on rats and mice subjected to the same signals, as well as to mobile telephony signals, proved to be negative.

The Perform C programme, which is focusing on several physiological parameters (sleep, cognitive functions, symptoms, etc.), is currently being conducted on volunteers at Stockholm's Karolinska Institute.

44 Ornithin-decarboxylase

10.2.2 The GUARD programme (Potential adverse effects of GSM cellular phones on hearing)

The goal of this programme, which was completed at the end of 2004, was to evaluate the specific effects on hearing, in both humans and animals, of the low-intensity RF fields produced by mobile phones at the 900 and 1800 MHz frequencies. Nine teams from seven European countries are participating in this project, two teams doing animal research and the others working with humans.

Human studies*:* A feasibility study defined the minimum number of subjects required to produce a significant effect for intra-subject (stage I) and inter-subject studies (stage II).

Another study defined the exposure parameters for the subjects.

In stage I, the acute effects on hearing of an exposure of short duration (10 minutes) at the maximum level (2 W peak at 900 MHz and 1 W peak at 1800 MHz) were researched on a total of 500 normal subjects. No effect was demonstrated at this stage.

In stage II, two subject groups were compared (i.e. intensive and occasional users of mobile phones). The data are currently being analyzed.

Animal studies: Experiments on rats exposed or pseudo-exposed to 900 or 1800 MHz, (2 W/kg, 2 h/d, 5 d/w for 4 weeks) did not show any effects on the function of the internal ear (from otoacoustic emissions).

A series of experiments has broached the problem of a possible potentiation of pathogenic effects of certain (ototoxic) agents on the internal ear during simultaneous exposure to GSM waves.

Thus the effects of semi-chronic exposure in guinea pigs (2 h/d, 5 d/w, for 2 to 4 weeks, at 900 MHz, 2 and 4 W/kg via a loop antenna) were studied in control animals (pseudo-exposed to GSM), and simultaneously exposed or pseudo-exposed to GSM and subjected to injections of gentamicine at doses of 60 and 75 mg/kg. Although threshold effects of the gentamicine were observed (i.e. slight high-frequency hearing loss, diminished olivocochlear efferent function), no differences were observed between the exposed and pseudo-exposed animals.

Similar experiments are currently underway in the rat.

In-vitro research is being conducted on the effects of GSM exposure (2 W/kg, 24 h) on the development of the organ of Corti of newborn rats in culture, with and without the presence of gentamicine at various concentrations. Here too, one observes the well-known effects of gentamicine, but no difference between the exposed and pseudo-exposed cultures.

10.2.3 INTERPHONE

This international study on the risks of tumours of the head related to mobile phone exposure is in the process of analysis. The preliminary results of the study, encompassing all of the participating countries, should appear during the course of 2005. A number of publications relating to this programme have already appeared and have been analyzed above. The studies strong points include: good statistical power due to the number of subjects participating in the study and good exposure characterization in the various tissues of the head (the characteristics of the devices and networks, as well as other sources of radiation, are taken into account). On the other hand, this study does not provide conclusive evidence concerning the specific risks incurred by children. Similarly, there could be a certain lack of perspective over time, which makes it more difficult to reach conclusive results if the latency period of a possible effect is longer than the period studied.

10.2.4 REFLEX[45]

This European programme was coordinated by the Verum Foundation in Munich. Twelve laboratories were involved in this multicentric study on the effects of very low-frequency RF fields on cellular systems (*in vitro*). This summary therefore only concerns the results related to RF fields.

A part of the results from the Reflex programme have been released in publications included in this report (see section 5.3.2) or were included in the preceding report. In Germany, *Czyz et al. (2004)* have shown that signals of the GSM-1800 type negatively regulate the expression of neuronal differentiation genes in precursor stem cells, while they positively regulate the expression of early response genes. This effect has been specifically observed in embryonic stem cells deficient in the p53 gene, but not in cells presenting a normal p53 gene. The Leszczynski group in Finland (*Leszczynski et al., 2002*[46]*, 2004; Nylund et al. 2004*) has shown by proteomic analysis that human endothelial cell lines exposed to a signal of the GSM-900 type present a modified protein expression and phosphorylation profile, for as yet unidentified proteins for the most part, with the exception of HSP27. *Capri et al. (2004)* have not detected any effect on the apoptosis and expression of HSP70 in the blood cells of either young or mature donors.

45 Risk evaluation of potential environmental hazards from low energy electromagnetic field (EMF) exposure using sensitive *in vitro* methods
46 Leszczynski D., Joenväärä S., Reivinen J., Kuokka, R., Differentiation, 2002, 70, 120–129.

Other Reflex data have shown genotoxic effects in different types of cells, particularly in human fibroblasts, granulosa cells and HL60 cells. These cells responded to RF exposures of between 0.3 and 2 W/kg with a significant increase in simple and double-strand DNA breaks and in the frequency of micronuclei (non-published results). It may seem surprising that the effects of RF radiation are only observable in a narrow range of SAR values. Moreover, the results on DNA damage are in contradiction with the most recent data (see section 5.3.2 and the reports of the Perform B and Cemfec European programmes).

Otherwise, no effect has been detected on the various other parameters, particularly apoptosis and cellular proliferation.

In conclusion, although it may appear advisable to conduct animal research in line with the Reflex data on HSP expression, studies confirming the “positive” genotoxicity results are crucial for their validation.

10.2.5 CEMFEC

Within the framework of the CEMFEC programme (fifth RDFP), coordinated by the University of Kuopio, the co-carcinogenic effects of 900 MHz GSM signals at low doses have been studied on animals (Wistar rats). The carcinogen used to induce cancers was the mutagen MX introduced in drinking water. The animals were exposed to 0.3 or 0.9 W/kg, two hours per day, five days a week. At the end of two years, tissue samples were taken and examined in histopathology. Blood samples were taken for genotoxicity tests at 3, 6 and 24 months. Cerebral tissue and hepatic tissue were sampled at the end of the experiment for the same purpose.

In vitro studies using two cell lines have also been conducted. In addition to MX, another carcinogen, the fungicide Vinclozolin, has been tested in combination with exposure to RF radiation on the NIH3T3 and L929 mammal cell lines. Several tests have been conducted, including oxidative stress, cellular proliferation, analysis of the cellular cycle, apoptosis, modifications of mitochondrial membrane potential and gene expression tests (the proto-oncogenes c-fos, c-jun and c-myc). SAR levels were similar to those used for animal testing (0.3 and 1 W/kg).

The results of the animal experiments have confirmed the carcinogenic effect of the MX, but RF exposure does not significantly increase the incidence of tumours. Nor does RF exposure induce a genotoxic effect in blood, liver or brain cells. RF energy does not have an effect on the DNA of liver or brain cells.

In vitro experiments show no effect on oxidative stress, apoptosis, mitochondrial membrane potential or oncogene expression. However, RF exposure alone or in combination with chemical exposure decreases cellular growth (this effect only appears after 24 hours of exposure).

The authors have concluded that, given the current state of knowledge of the mechanisms of carcinogenesis, the existence of a “protective” effect against DNA damage and the slight decrease in the proliferation of exposed cells would suggest a reduction rather than an increase in the cancer risk.

The fact that SAR levels greater than 1 W/kg were not used limits the comprehensiveness of the project. However, the use of higher SAR levels would have induced thermal effects that would have created problems for the interpretation of results.

In conclusion, the results of the CEMFEC study must be interpreted in the light of the results of other studies already completed or underway that have used other experimental models and different exposure levels.

10.3 National Toxicology Program (USA)

A new request for proposals has been launched by the NTP for a large-scale animal study following the NTP's standardized protocol (rats and mice, males and females, number of animals per group, etc.). The response to this RFP came from biologists in the United States and engineers in Switzerland for a total cost of $20 million with a duration of five years. Several mobile telephony signals will be used. The animals will be able to move about freely and will be exposed for most of the day. The results of this major research project, if it finally gets underway, will therefore not be available for the CIRC and ICNIRP evaluations.

10.4 Japan

The Japanese Ministry of Labour and Health has undertaken research on the possible effects of ELF and RF electromagnetic fields. Studies concerning the general public are directed by the National Public Health Institute and those on the workers by the Industrial Health and Safety Association. In 1998, the Post and Telecommunications Ministry (MPHPT) established a committee responsible for supervising research on the health effects of RF radiation. The second term of this committee has been extended up to 2007. The average annual research budget is €3 million.

The Association of Radio Industries and Businesses (ARIB) and the mobile operator NTT DoCoMo are also involved in the research.

10.5 South Korea

In 2000, the Ministry of Information and Communication (MIC) launched a five-year research programme on electromagnetic fields, and this year is therefore its last year of activity. The overall budget is approximately €8 million.

Planning for a second stage of the programme is underway.

Epidemiological studies include the incidence of cancer around medium-wave transmitters and participation in the Interphone study.

A large-scale study on volunteers is underway on the effects of mobile phones on certain cerebral functions and other physiological functions (2002-2005). Animal and cellular studies have also been initiated as well as projects concerning the design of exposure systems.

There is a website providing information for the public on the research and on risk management (www.emf.or.kr).

10.6 Australia

In 1996, in response to fears expressed by the public in the face of possible health risks from mobile phones, the Australian federal government allocated 3.4 million Australian dollars (approximately €2 million) to the National Health and Medical Research Council (NHMRC)[47] to finance a RF research programme. Four projects were subsidized by this programme between 1997 and 2000, including both human and animal studies. Research on volunteers and the general population focused on the increase in the brain tumour risk and on memory, while the fundamental research was aimed at determining whether or not electromagnetic fields produce cancer in mice. Additional funding of €300 thousand was allocated for the 2001-2003 period, to finance two projects on human physiological responses to exposure to radiation from mobile phones and the effects of long-term exposure on vision and hearing. A recommendation for subsidies of more than €300 thousand annually was approved for the next five years by the Ministry of the Health in June 2003. The creation of a Centre for Research Excellence in Electromagnetic Energy has been approved to conduct this research.

10.7 National European Programmes

10.7.1 France

10.7.1.1 ACI

Following the COMOBIO programme, funding was requested so that the French research effort on the health effects of mobile telephony could continue. In 2004, an "*action concertée incitative*" (ACI – concerted incentive initiative) was started on this topic with funding of €500 thousand over three years from the Ministry of Research, with additional funding from mobile phone operators for salaries (€300 thousand). Seven projects have been selected (see the table below).

René De Seze	INERIS, Verneuil-en-Halatte	Effects of radiofrequency fields on the neurotransmitters and receptors of the central nervous system of rats
Thérèse Jay	University of Paris	Potential effects of GSM and UMTS signals on cerebral tissue: study of thermal shock proteins and inflammatory reactions
Isabelle Lagroye	CNRS/EPHE, Pessac	Study of the effects of mobile telephony signals on the central nervous system: stress proteins, inflammation, genotoxicity
Gérard Ledoigt	University of Aubière	Effect of high-frequency non-ionizing electromagnetic radiation (NIR) on living organisms
Lluis Mir	IGR, Villejuif	Analysis of the changes in the endocytosis of cultured cells provoked by *in vitro* exposure of the cells to pulsed electromagnetic fields
Tabony James	CRSSA, Grenoble	Study of the triggering of the self-organization of microtubules by low-intensity electromagnetic fields at 1800 GHz
Justin Teissié	CNRS, Toulouse	Destabilization of the cell wall-plasma membrane interface by mobile telephone-related electromagnetic waves

47 National Health and Medical Research Council

10.7.1.2 National environmental health plan

A “Plan National Santé Environnement” (PNSE – National environmental health plan) has been set up for the 2004-2008 period. The objectives of this plan are to:

- ensure good air and water quality
- prevent pathologies of environmental origin and particularly cancers
- better inform the public and protect at-risk populations (children and pregnant women).

The plan is in keeping with an approach initiated several years ago aimed at improving risk evaluation and management measures, particularly by strengthening resources, as well as the quality and independence of expertise in the field of environmental health (through the creation of specialized agencies such as the AFSSE). A certain number of “initiatives” have been defined: the initiatives concerning the mobilization and development of the research potential in the field are of particular interest (Initiatives 30, 31, 32, 33, 34). The area of electromagnetic fields is not dealt with specifically in this plan, but only within the framework of the “mobile telephony” plan announced on 17 December 2003. For the record, this plan is divided into three parts: (i) the development of research and the deployment of a techno-watch initiative with follow-up of populations that consider themselves affected by these electromagnetic fields, (ii) reinforcement of regulations, (iii) a guarantee of transparency of information.

10.7.2 Switzerland

In Switzerland, the major share of the research is coordinated by the “Swiss Research Foundation on Mobile Communications”, a non-profit making association created in 2002 by three Swiss operators and the Polytechnic Institute of Zurich. Projects are evaluated and support decisions made by an independent scientific committee. The annual research budget is approximately €350 thousand. The projects are divided between fundamental research (*in vitro* and *in vivo* studies, dosimetry and human studies) and risk perception and communication. Of the eighteen projects subsidized to date, seven were completed in 2003, and seven in 2004. Of the four projects currently underway (all in fundamental research), three will be completed in 2005, including a replication of the Dutch “TNO” study.

10.7.3 Great Britain

The British MTHR research programme[48] – “Mobile Telecommunications Health Research” – was launched in 2001, with 15 research projects at the start. In January 2004, two new projects were approved: a study on volunteers to determine whether emissions from base stations provoke symptoms and a study on the perception of risk associated with mobile phones and base stations. In November 2004, several new projects were added: the evaluation of a personal exposure meter for use in epidemiology, and an experimental study of the role of ELF signal modulation. Several projects included in the MTHR programme have now been completed, including projects on the impact of hands-free kits on driving, the interaction of TETRA signals with the head, the measurement of ELF emissions by mobile phones and the feasibility of a cohort study in connection with brain cancers and neuro-degenerative diseases.

48 Mobile Telecommunications and Health Research Programme

10.7.4 Denmark

A national research programme on the health effects of RF exposure was launched in 2004. Five projects have been already subsidized by the Danish government for a total of approximately €2 million. Additional funding should be obtained in 2005. Epidemiological research includes the definition of a Danish cohort for an international study promoted by the WHO, participation in a joint analysis by the Scandinavian countries of the brain tumour risk, and the follow-up of an already completed Danish study on brain tumours. The other studies include: an attempt to replicate the “TNO” study, effects on the metabolism of the brain by Positron Emission Tomography (PET); the effects on the quality of sperm and the reproductive hormones in young users of mobile phones; the combined action of geomagnetic and RF fields on biochemical reactions according to the mechanistic hypothesis of free-radical pairs.

10.7.5 Germany

During recent years, €8.5 million have been spent in Germany on research programmes on the potential adverse effects of mobile telephony emissions (epidemiology and laboratory studies, www.emf-forschungsprogramm.de). The current programme was launched in 2002 by the Ministry of the Environment, Nature and Nuclear Safety. It is co-funded by the ministries and by operators in the amount of €17 million and will be completed in 2006. To date, 24 research projects are underway, half of which are in the field of biology. Among the various topics dealt with are the role of signal modulation, the effects on DNA and the cell cycle, the role of oxygenated free radicals, animal models of leukaemia, an overview of melatonin, cognitive functions in the rat, German participation in Interphone, etc.

10.7.6 Italy

A national project, entitled “Protection of populations and the environment against electromagnetic emissions” was officially completed in May 2004. The project was 50 per cent funded by the Ministry of Education and Research, and 50 per cent by the participating research units. While the programme is closed from the budgetary standpoint, several studies are continuing until their completion.

A similar situation exists with studies financed through international cooperative efforts in the context of the fifth RDFP of the European Union. Italy is the only country participating in all projects approved and funded by the European Union. Most of these studies were recently completed and reports and summaries of the main results are currently being drawn up.

No new national projects are planned in the near future. In fact, in contrast with what happened during the fifth RDFP, electromagnetic fields are not considered a research priority, and no new studies will be funded under this programme. As a result of budget cuts undertaken to deal with economic problems, there is now a concern about the future involvement of Italian research in this field, which could slow down considerably in years to come.

10.7.7 Finland

Research activity remains intense in Finland. During the 2000-2003 period, the “La Vita” programme received annual funding of €1.3 million (70 per cent from the government and 30 per cent from industry). The current programme (2004-2006) deals with the following topics: cognitive functions, the cardiovascular system, activity of the enzyme ornithin-decarboxylase, dosimetry, the search for biomarkers, etc.

11 RESEARCH RECOMMENDATIONS

Research in France must be conducted within the framework of the recommendations made by the WHO (cf. Appendix c).

Nous vous remercions pour les premiers éléments d'analyse que vous nous avez communiqués sur la validité et les conclusions de cette étude. Ils soulignent la nature controversée des résultats et suggèrent des propositions d'études complémentaires. C'est pourquoi nous vous demandons d'explorer plus avant :

- les conditions de la pertinence de telles études,
- leur faisabilité technique et financière,
- les problèmes méthodologiques et les biais de sélection dans les groupes témoins qu'il conviendrait d'éviter pour une interprétation fiable des résultats.

Sur ce dernier point, nous vous suggérons notamment de vous mettre en rapport avec l'Institut de veille sanitaire.

Nous vous prions d'agréer, Madame la Directrice Générale, l'assurance de notre considération distinguée.

La directeur général de la santé

Professeur William DAB

Le directeur des études économiques
et de l'évaluation environnementale

[illegible]

11.1 Children

The WHO research programme serves as the basis for research to be conducted. The expert group recommends in particular that research on children should be continued, especially in the field of dosimetry and through animal experiments, including *in utero* exposures.

Moreover, a new project of the Interphone type in children is under consideration at the International Cancer Research Centre. An application for the funding for a feasibility study will be submitted to the European Union if the results of the Interphone study suggest that there is a doubt about potential carcinogenic effects. It would be advisable for France to participate in this study if it is implemented (keeping in mind that when such studies are conducted by a single researcher, one will always encounter the problem of limited statistical power, in view of the rarity of the effects being researched).

11.2 Workers

Persons working in the RF sector (i.e. maintenance workers as defined by European directive 2004/40/EC on occupational safety, published 30 April 2004) can in some cases be very highly exposed to RF radiation. The expert group is requesting that it be made mandatory to regularly record the exposure of exposed employees and establish a Register of employees in this sector for the purposes of a future epidemiological study, if such a study appears to be warranted. This measure should also be applied to employees not concerned by this directive, but who perform work in locations near antennas (roofers, for example).

As regards workers whose work exposure to mobile telephony is significant but who are not recognized as exposed workers under occupational safety directive 2004/40/EC, the expert group noted that intensive use can result in a substantial amount of overall exposure and place employees in a situation of stress on account of the state of constant availability in which they are placed (availability which is sometimes associated with specific physical constraints or risk of accidents). The expert group expressed the wish that this situation be investigated so that the extent of this phenomenon can be measured (through the SUMER study or the “working conditions” survey, for example) so that consideration can later be given to undertaking the necessary research, or so that specific measures can be taken, if necessary.

11.3 Base stations

It is crucial to respond to the public's concerns, particularly in light of the proliferation of base stations with the development of third generation networks.

The need for individual assessments (via personal exposure meters) was stressed by the expert group, with the objective of conducting future population studies on base stations.

The participation of France in a cohort study focused on base stations on an international scale will be evaluated if such a study is launched. The results of the “Interphone” study and a demonstration of the feasibility of this type of study, particularly as regards the crucial element of exposure evaluation (as well as the availability of standard dosimetry techniques that can be easily applied on a sufficient scale), are some of the elements that will be taken into account in the decision to launch such a study.

11.4 Dosimetry

11.4.1 Mobile devices

SAR measurement protocols must take into account the position of the hand, which absorbs approximately 20 per cent of the energy and thus decreases the energy used for the call (leading to an increase in the power required to obtain a good transmission quality).

Research needs to be conducted to measure “local” SAR, when the devices are worn at a certain distance from the head (at the level of the heart or belt, for example).

11.4.2 Hands-free kits

Measurement protocols must be designed and each device must undergo systematic testing with the phone with which it is to be used. A proactive attitude on the part of France would allow it make proposals at Cenelec where such measurement protocols are discussed and adopted by the international community. The final objective should be that the kits reduce the absolute SAR of the “mobile phone plus kit” as a whole, keeping in mind that SARs of 0.01 W/kg are not measurable.

Lastly, it would be desirable to have SAR measurements for wireless hands-free kits (Bluetooth, etc.).

11.5 The research foundation[49]

The *Fondation Santé et radiofréquences* (FSR – Radiofrequencies and health foundation) should ensure the independence of researchers, and thereby promote funding for research. The expert group is requesting that this funding be supplied by regular resources whose distribution should be controlled by a scientific committee.

12 RISK MANAGEMENT RECOMMENDATIONS

In view of the results of epidemiological studies (which are still only partial as regards the Interphone study), and while awaiting the results of as yet unpublished experimental studies on the haematoencephalic barrier, the group feels that it is still not possible to draw final conclusions concerning the health effects of electromagnetic fields associated with mobile telephony radio waves.

Because of this, the expert group recognizes the relevance of the opinion of the AFSSE which, in 2003, advocated a precautionary approach for mobile phones and the principle of caution for base stations. Moreover, **the group recommends the mandatory application of the provisions contained in the circular of October 2001 and its future updates (under the form of a technical guide made mandatory via regulatory channels).**

12.1 The approach of the World Health Organization

The WHO has developed a new structure for precautionary approaches, in order promote a clearer perspective on the issues raised by the precautionary principle, through the proposal of a text on a “framework for precaution”. This framework proposes a systematic approach for the implementation of

49 Decree of 10 January 2005 published in the official gazette of 13 January 2005, p.554

precautionary options in the face of both known and unknown effects. The “electromagnetic fields” unit of the WHO has prepared case studies for both main frequency ranges. Appendix C of this document concerns RF fields (the document can be consulted on the WHO's website: http://www.who.int/peh-emf/en/).

12.2 Control of exposure

12.2.1 Display of SAR values and the efficiency of terminals

The public authorities must see to it that regulations are applied, particularly as regards the display of mobile phone SAR values. The experts recommend that SAR values be displayed at points of sale and that hands-free kits be supplied with all phones. It should be remembered that the quality of a mobile phone does not only depend on its SAR value but also on its capacity to pick up the network (i.e. its sensitivity and radiant intensity) resulting in good quality communication. It would be preferable if these two elements were taken into account (and not just the SAR value) in measurement standards NF-EN-50360 and 50361.

12.2.2 Exposure from mobile phones

Within the framework of the recommended precautionary approach, the expert group recommends that users should make an effort to decrease exposure while using mobile phones. Some common sense measures should be kept in mind: limit the call time, make calls in good reception zones, keep the phone away from the head. On this last point, it was proposed in the 2003 report that hands-free kits should be used on a systematic basis. It is evident, however, that in actual practice such kits are rarely used, especially by children. An incentive action should be undertaken to encourage their use.

12.2.3 Exposure from base stations

The average exposure level from mobile phone installations could increase with the increase in GSM traffic, the introduction of UMTS, and initially, with the simultaneous use of the two systems. Exposure levels must be continuously evaluated, particularly in heavy traffic areas. Networks must continue to be deployed in close consultation with the population and elected representatives and with a constant concern for integration.

Overview of radio frequencies:

A comprehensive plan for taking measurement **samples** (at all frequencies and in all configurations) should be implemented by the public authorities, which will complement the measurements made at the request of individuals and municipalities, in order to ensure that the measurements taken are **representative** of the exposure of the French population.

Low-power transmitters:

The public authorities must enforce the application of the circular of October 2001 (and any document that replaces it) to micro- and pico-cells.

12.3 Children

The expert group advocates much the same measures as those advocated by the NRPB (see paragraphs 59-61 of the NRPB's 2004 report).

As regards head exposure by children to mobile phones, in the absence of new data and in view of the continuing uncertainties, the expert group maintains the recommendation of its 2003 report. **It recommends that all reasonable means be taken to limit the exposure of children to the lowest possible level** (via hands-free kits, information campaigns for parents and young people, the use of phones with minimal SAR values and recommendations on the proper way to use mobile phones).

Road safety training in the educational environment must inculcate basic knowledge of the risks of using mobile phones while driving any type of vehicle.

It would be a good idea to establish specific rules governing the marketing of mobile phones to captive populations such as children (i.e. manufacturers must not encourage increased use of mobile phones by children by means of advertising or by designing models that are particularly entertaining and attractive to children).

12.4 Workers

The expert group is aware that increasing numbers of employees are being required to make intensive use of mobile phones in connection with their work. **A precautionary approach, advocating a decrease in mobile phone exposure in the work environment, particularly while driving, must also be applied to this category of people.**

12.5 Mobile phone use while driving

Even though the relative risk of traffic accidents related to the use of mobile phones while driving appears to be lower than initially thought, there is nonetheless a very real risk, even with the use of hands-free kits, since vigilance tends to decrease during mobile phone use. The expert group therefore recommends increased vigilance concerning the equipment installed by the automobile manufacturers: **hands-free kits must not under any circumstances be used as sales arguments and even less as safety arguments.**

Furthermore, the public authorities must enforce the application of regulations prohibiting the use of handheld devices while driving.

13 COMMUNICATION OF RISK

13.1 Initiatives and results

Several initiatives have been recently undertaken to inform the public:

- a website indicating the location of all base stations and the results of RF field measurements is currently available (cf. Cartoradio above);

- an exhibition devoted to mobile telephony at the Cité des Sciences in La Villette, sponsored by Orange, will continue up to the summer of 2005. It includes exhibits on health questions.

Some new initiatives should also be deployed, thanks in particular to the FSR (Radiofrequencies and health foundation):

- the WHO has translated a manual for the communication of risk associated with electromagnetic fields into French. It is hoped that this document will be widely distributed in France;

- on its Internet site, the AFSSE plans to offer information in the form of a quarterly scientific update, which would summarize progress in research and its consequences for public health.

13.2 The mandatory introduction of environmental health training

In the opinion of the members of the expert group, it is **vital and urgent** to include in the curricula of certain professions (i.e. doctors, pharmacists, veterinarians, etc.) training on the relationship between health and the environment; in fact, this field raises increasingly numerous and frequent questions and the health professions represent the natural interface between the public and the scientific and public authorities. Their current lack of training in this field prevents them from effectively fulfilling their role as advisors and watchpersons. Similarly, postgraduate continuing education for the health professions must be offered for currently active professionals.

14 SUMMARY

The expert group would like to draw attention to the incredibly rapid development of the use of radiofrequency technologies during recent years and the substantial number of persons using these devices. It has compiled and interpreted the new results from worldwide research and formulated research recommendations, which are in agreement with those of the WHO.

It also offers a certain number of risk management guidelines.

14.1 Evaluation of risk

14.1.1 Mobile phones

The expert group feels that it cannot currently draw definitive conclusions concerning the existence of adverse health effects caused by the electromagnetic fields resulting from mobile telephony. This scientific judgement is founded on:

- the lack of historical perspective of the epidemiological studies published to date on cancer and their lack of statistical power, making it impossible to specifically inventory the dose-effect relationship,
- the recent Swedish publication indicating a possible increase in neurinomas of the auditory nerve in the ear exposed to the mobile phone, along with the positive results of an earlier Swedish study and the negative Danish results concerning incidence,
- the new negative epidemiological results from Sweden concerning other tumours of the head,
- the insufficiency of data concerning other types of diseases or specific populations (e.g. children),
- the mainly negative experimental results, and the wait for data from the major projects currently underway (particularly on the permeability of the haematoencephalic membrane and the copromotion of tumours).

The expert group therefore recommends that an attitude of scientific vigilance should be maintained while awaiting the results of the Interphone study, which should clarify a certain number of issues due to its scope and statistical power, as well as the results of the large experimental replication studies still underway.

The expert group also recommends that research should be undertaken on the populations potentially most at risk (such as children) and that studies on the possible adverse health effects of new signals should be continued.

14.1.2 Base stations

As regards the potential adverse health effects of base stations, the expert group concludes that no new study has shown convincing evidence of such effects. In the current state of scientific knowledge, such effects have not been conclusively demonstrated.

The expert group stresses the need, however, to evaluate new personal exposure devices (exposure meters), which are the only way to determine the actual levels of exposure to RF fields in conjunction with future large-scale epidemiological studies conducted in the general population.

14.1.3 The TNO study

The expert group concludes that due to the numerous deficiencies in the protocol of the so-called "TNO" study, it is necessary to wait for the results of the replication studies currently underway before contemplating new studies.

14.2 Risk management

In the area of risk management, the expert group acknowledges the relevance of the recommendations of the AFSSE and recommends that the application of the provisions contained in the circular of October 2001 and of its future updates be made mandatory.

14.2.1 Mobile phones

The precautionary approach recommended by the AFSSE entails endeavours to decrease exposure to mobile phones, which must be applied to the entire population, including children, people using mobile phones in connection with their work, etc. In particular, all means to limit exposure must be studied, including:

- initiatives to facilitate the use of hands-free kits by as many people as possible or to promote the "user-friendliness" of such kits to encourage their adoption by the general population,
- phones with minimal SAR levels,
- information campaigns for parents and young people,
- recommendations on proper mobile phone use,
- control of advertising, etc.

The final objective should be that the kits reduce the absolute SAR of the "mobile phone plus kit" as a whole, keeping in mind that SARs of 0.01 W/kg are not measurable.

14.2.2 Base stations

In spite of the lack of conclusive results on the health effects of base stations, the principle of precaution advocated by the AFSSE must be implemented while remaining attentive to complaints, which can serve as warning signs. Suitable measures must be undertaken in this regard.

When new networks are deployed, an attitude of continuous dialogue with local government officials and the public must be the rule (with application of the AMF-AFOM best practices guide).

A comprehensive plan for taking measurement samples (at all frequencies and in all configurations) should be implemented by the public authorities, in order to ensure that the measurements taken are representative of the exposure of the French population.

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16 MEMBERS OF THE EXPERT GROUP

Jean Marie Aran is a research director at Inserm, with an engineering degree from ENSERB and a doctorate in the natural sciences. He joined the *Institut national de la santé et de la recherche médical* (Inserm – National Institute for Health and Medical Research) in 1965 and currently works at the Experimental Audiology Lab (now known as the Laboratory of cellular and molecular biology of hearing) in Bordeaux, which he directed in the form of a research team or Inserm Unit from 1976 to 1992. His scientific work, conducted in this laboratory and at the Kresge Hearing Research Institute of the University of Michigan in Ann Arbor, in the United States, has been focused mainly on the physiology and physiopathology of the internal ear. He contributed in particular to the development of new electrophysiological methods for the functional exploration of hearing, and to the understanding of the ototoxic mechanisms of certain agents, such as aminoglycosidic antibiotics. From 1983 to 2001 he was editor-in-chief of the international journal *Audiology*. He is currently participating in the European research programme, GUARD (Potential Adverse Effects of GSM Cellular Phones on Hearing). He is a Chevalier in the French Order of Merit.

Alain Azoulay holds an engineering degree from the *Ecole Supérieure d'Electricité* (ESE – Advanced Electrical Studies Institute). He was a consulting engineer with the Thomson CSF company in the microwave radio systems division and a consulting engineer in “radiofrequency propagation” for the “Antennas and Hertzian propagation department” of the *Centre national d'études des télécommunications* (CNET – National Centre for Telecommunications Studies). He subsequently headed up the CNET's “radiofrequency disturbances” group, and was later put in charge of various other departments at CNET, including “Electromagnetic compatibility,” “Terrestrial radio communications and electromagnetic compatibility,” “Radio communications for mobile phones, access networks and electromagnetic compatibility.” He also directed the “Antennas, expertise and RF measurements” department at the TDF's technical centre. Since 1997, he has been teaching at the ESE, after teaching at the *Ecole Centrale de Paris* (ECP – Paris Engineering School) in the field of electromagnetic compatibility. His current research activity concerns field measurements for new radio communications and broadcasting systems, as well as the use of reverberating chambers to characterize radiofrequency emissions. He is the author of numerous publications in both French and international scientific journals, has presented scientific papers at international conferences and is a member of several international standardization groups.

Pierre Buser is a graduate of the *Ecole Normale Supérieure of Ulm* (ENS Ulm), and has an advanced degree (*agrégation*) in biology and a State doctorate in science. He was named lecturer and then assistant professor in the Sciences division of the University of Paris, then professor of neurosciences at the Pierre and Marie Curie University in Paris and director of the Neurosciences Institute of the CNRS at the UPMC. In 1991, he was named Professor Emeritus at the same University. He was appointed first a corresponding member of the Academy of Sciences, and a full member of Academy of Sciences in 1988. He was awarded the Bing prize from the Swiss Academy of Medical Sciences and the Fyssen Foundation's international prize. His research has given rise to numerous specialized publications in the field of cerebral mechanisms (i.e. sensorial neurophysiology, motricity and behaviour). He has also contributed to several works in the fields of neurophysiology, vision, hearing and neurobiology. He is a chevalier in the Legion of Honour, an officer in the French Order of Merit and an officer in the *Ordre des Palmes Académiques*.

Frédéric Couturier has an electrical engineering degree from EUDIL, and is the engineering authority for the Spectrum Control Technical Division of the ANFR. He participates in the European research of the European Post and Telecommunications Conference and in the international research of the International Telecommunications Union in the field of radiofrequency emissions control. Beginning in 2000, he successively chaired the French and then the European group for the development of an *in situ* measurement protocol for non-ionizing radiation. Since 2001, he has been a regular contributor to the ANFR's overview of electromagnetic radiation in France.

Jean-Claude Debouzy is a graduate of the Bordeaux Naval School of Health, and is currently chief of staff and head of the Cellular and Molecular Biophysics Unit of the Armed Forces Health Service's research centre. His doctoral thesis in Sciences at the University of Paris-VI dealt with the application of nuclear magnetic resonance methods to the study of biological problems. His research is focused on drug/membrane and drug/DNA interactions, using spectroscopic methods (NMR-EPR), as well as on the decontamination/chelation of heavy ions in biological environments by means of modified cyclodextrins. The majority of the 75 articles he has published to date concern this research. Since 1995, he has concentrated his efforts on the biological effects of non-ionizing radiation. In this regard, he is member of the International Union of Radio Science (URSI), the Bioelectromagnetics Society (BEMS), the Biophysical Society and the French Biophysics Society, and participates in NATO committees concerning electromagnetic radiation hazards (RADHAZ). He has been an associate professor at Val de Grâce since 2002, and was named a chevalier of the Legion of Honour and of the Order of Merit.

Martine Hours is a medical epidemiologist and specialist in public health and occupational medicine. She completed a doctoral thesis in the Sciences and was a researcher at the Claude Bernard-Lyon I University, first at the Institute of Epidemiology and then at the Institute of Occupational Medicine where she developed epidemiological research in the fields of occupational and environmental health, particularly as regards mobile telephony. She participated in the research of the *Réseau Santé-Déchets* (Health Waste Network), during which she set up studies on vocational risks in the waste-treatment sector. Following the creation of the Transport, Work and Environment Epidemiology and Health Observatory Laboratory (UMRESTTE), (UMR No. 9002 Inrets/UCBL/InVS), she was responsible for research at the French National Institute for Transport and Safety Research (INRETS), focusing a part of her activities on research in accidentology. She is the French coordinator for the international "Interphone" study sponsored by the WHO. She is also a member of the BEMS and the EBEA.

Isabelle Lagroye is a biologist with a doctorate in Pharmacy and the Life Sciences. She is a lecturer at the bioelectromagnetics laboratory of the *Ecole Pratique des Hautes Etudes*, associated with the PIOM laboratory (i.e. physics of wave-matter interaction) at the *Ecole Nationale Supérieure* of Physical Chemistry of the University Bordeaux I. For the last ten years she has been researching the biological effects of electromagnetic waves. She is responsible for various programmes for the study of the effects of mobile telephony-related RF fields on the brain, particularly within the framework of the ACI (*action concertée incitative* or concerted incentive initiative) for "mobile telephony and health".

She is currently a member of the *Conseil Supérieur d'Hygiène Publique de France* (CSHPF – French Public Health Board) (Life sciences division) and of several societies (SFRP, EBEA, BEMS).

Michel Terre is an engineer at the National Communications Institute and holds a doctorate from the Paris *Conservatoire National des Arts et Métiers* (CNAMP – National Conservatory of Arts and Trades of Paris). He successively served as a consulting engineer for TRT, Thomson CSF and Alcatel. He directed the Signal Image Telecommunications department of the *Institut Supérieur d'Electronique de Paris* (ISEP – Paris Institute for Advanced Electronic Studies). Since September 1998, he has been a lecturer in radio communications at the CNAMP. His research work has been essentially oriented towards the optimization and the improvement of transmission systems and radio access. He is the author of peer-reviewed articles in French and international scientific journals and has presented numerous scientific papers at international conferences. He also holds several patents in the field of radio communications. He is a senior member of the SEE.

Paolo Vecchia is a physicist and director of research at the National Public Health Institute of Italy, in Rome. He conducts research in the Non-ionizing radiation group of the Technologies and Health department. For more than twenty years, he has performed research on the biological and human health effects of electromagnetic fields (for both low- and high-frequency fields). He has also participated in the research of numerous national and international commissions for the protection of workers and the public against the risks of non-ionizing radiation. He has taught in this field at the universities of Rome (Tor Vergata) and Pisa. He has served as chairman of the Italian Radiation Protection Association (AIRP) and of the European Bioelectromagnetics Association (EBEA). He is currently the chairman of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and of the coordinating committee of the COST281 initiative (on the potential adverse health effects of mobile telephony systems).

Bernard Veyret has a physical engineering degree from ESPCI, and a doctorate in Sciences. He is a CNRS research director at the Wave-Matter physics laboratory (PIOM) at the ENSCPB in Bordeaux. He is also director of the Bioelectromagnetics laboratory of the *Ecole Pratique des Hautes Etudes*. He has been conducting research on the biological effects of electromagnetic fields since 1985. He is a member of the board of the ICNIRP (International Commission on Non-Ionizing Radiation Protection) and chairman of the K Commission of the URSI (International Union of Radio Science). He was previously the scientific director of the French Comobio research project and director of the European Perform-B research programme on the potential adverse health effects of mobile telephony.

17 ACRONYMS AND ABBREVIATIONS

BCCH	Beacon channel (GSM)
BEMS	Bioelectromagnetics Society
CDMA	Code Division Multiple Access A method of accessing the microwave channel used by certain mobile telephony networks by means of a pseudo-random personal code.
COST	Cooperation in Science and Technology
CSO	Centre de Sociologie des Organisations (Center for the Sociology of Organizations)
EBEA	European BioElectromagnetics Association
EDGE	Enhanced Data Rate for GSM Evolution. An intermediate technology between GSM and UMTS.
EEG	Electroencephalogram
FGF	Forschungsgemeinschaft Funk. A German research organization in the field of radio applications.
GPRS	General Packet Radio Service. A high-bandwidth technology for the radio transmission of data.
GPS	Global Positioning System
HEB	Haematoencephalic barrier
HSP	Heat Shock Protein
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IECS	International Committee on Electromagnetic Safety
IRPA	International Radiation Protection Association
NMT	Nordic Mobile Telephone. A standard for analogue cellular radiotelephony.
NRPB	National Radiological Protection Board. Great Britain's radiation protection agency.
RF	Radiofrequencies
SSI:	Statens strålskyddsinstitut. Swedish Radiation Protection Agency.
TDMA	Time Division Multiple Access
TETRA	Terrestrial Trunked Radio Access. A radio communications standard for professional use.
TNO	Netherlands Organization for Applied Scientific Research
UMTS	Universal Mobile Telecommunications System
WI-FI	Wireless Fidelity Cooperation in Science and Technology
WHO	World Health Organization
WLAN	Wireless Local Area Network. A high-frequency radio wave wireless local area network.

18 APPENDICES

Appendix a: Mission letter from the Director General of the AFSSE

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La Directrice Générale

MFV/GD/ALR2004 – n°1070

☎ : 01.56.29.19.37

Affaire suivie par : Dr Gilles DIXSAUT

Maisons-Alfort, le 27 AOUT 2004

Madame Martine Hours
INRETS
25 av François Mitterrand
69500 BRONS

Objet : Mission du groupe d'experts de l'AFSSE relatif à l'actualisation des données scientifiques sur les effets biologiques et sanitaires de la téléphonie mobile.

Madame,

Vous avez accepté de participer aux travaux du groupe d'experts « téléphonie mobile » de l'AFSSE et je tiens à vous en remercier. Avant d'engager plus avant les travaux de ce groupe, il m'apparaît utile d'en fixer avec précision la mission.

Depuis la publication du rapport du précédent groupe d'experts et de l'avis de l'AFSSE le 17 avril 2003, plusieurs rapports de synthèse sur la téléphonie mobile ont été publiés, en particulier le rapport britannique du NRPB, qui vise à faire un point complet de l'état des connaissance, le rapport du SSI, qui vise à faire une mise à jour rapide et régulière de l'état des connaissances, le rapport du Conseil de la santé hollandais qui vise également à faire une mise à jour rapide de l'état des connaissances, ainsi qu'un rapport suisse dont l'objet est le même..

L'AFSSE de son coté, conformément aux missions qui lui sont confiées par la loi, doit publier chaque année un document de mise à jour de l'état des connaissances. A cet effet, et dans l'attente de l'installation du comité d'experts spécialisé prévu dans le domaine des agents physiques et grands aménagements, en cours de constitution, et afin de ne pas retarder la publication de ce rapport il a été décidé de constituer un groupe d'experts ad hoc. La mission de ce groupe est d'abord de réaliser un inventaire et une évaluation des travaux scientifiques publiés depuis le dernier rapport remis à l'Agence par le groupe d'experts présidé par Bernard Veyret, ou en cours de publication dans le domaine des effets biologiques et sanitaires éventuels des installations et équipements de téléphonie mobile et de radiocommunication, qu'il s'agisse des rapports de synthèse ou des publications scientifiques originales. En outre une particulière attention devra être portée aux travaux relatifs aux nouvelles et futures technologies de radiocommunication, qu'elles relèvent strictement des applications de la téléphonie mobile ou de l'environnement de la téléphonie mobile. Je veux parler ici notamment des transmissions à courte portée, pour lesquelles il convient de se prononcer en termes d'effets sanitaires éventuels. L'objectif de cette évaluation n'est pas de faire un point complet de l'état des connaissances, mais de compléter les éléments du rapport précédent.

Sur le fondement de ses conclusions le groupe d'experts proposera le cas échéant des orientations en matière de gestion de risques qui auraient été identifiés en direction des pouvoirs publics. Le groupe d'experts présentera également ses recommandations en matière de recherches.

En outre, par courrier daté du 3 février 2004, les ministères en charge de la santé et de l'environnement ont chargé l'Agence française de sécurité sanitaire environnementale d'évaluer la faisabilité et la pertinence d'études complémentaires, destinées à dupliquer l'étude conduite par l'Institut de recherche technologique Néerlandais TNO, sur certains effets possibles des stations de base de téléphonie mobile, notamment en ce qui concerne les stations de base UMTS (étude non

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publiée à ce jour dans une revue scientifique). Une copie de cette saisine a été adressée à chacun d'entre vous.

Il ne m'est pas apparu nécessaire de créer un deuxième groupe d'experts ayant une mission spécifique afin de répondre à cette question particulière. C'est pourquoi, je vous propose d'intégrer dans le cadre de votre rapport les réponses aux questions posées dans cette saisine ministérielle, ainsi que vos propositions d'action. Ces éléments pourraient faire l'objet d'un chapitre particulier.

Le rapport rédigé par le groupe d'experts est destiné à être rendu public et, le cas échéant, à donner lieu à la publication d'un avis de l'Agence. Aussi, il me paraît important que le groupe d'experts s'attache à exposer dans le détail la méthode de travail qu'il aura suivie, avec en particulier des précisions sur :

i. les différentes sources d'informations utilisées (littérature scientifique, travaux scientifiques non encore publiés auditions/consultation d'experts, travaux de calculs et/ou de modélisation etc.) ainsi que les critères de sélection des informations retenues ;
ii. les critères de sélection des experts extérieurs éventuellement consultés ; les critères de sélection des données bibliographiques, et les bases de données utilisées – référencées dans la bibliographie du rapport -; une prééminence devra être donnée aux travaux issus d'organismes scientifiques officiels et aux revues scientifiques à comités de lecture ;
iii. les règles adoptées pour interpréter les données ainsi recueillies.

Afin de garantir l'indépendance de l'expertise, l'AFSSE veillera à ne pas interférer avec le déroulement du travail scientifique du groupe d'experts, sauf sur demande écrite du président du groupe d'experts. L'Agence assurera le secrétariat du travail scientifique (collecte des données, bibliographie, traitement statistique, compte-rendu des réunions etc.).

Je remercie Madame le docteur Martine Hours d'avoir accepté d'assurer la présidence du groupe d'experts.

Je souhaiterais pouvoir disposer des conclusions de vos travaux pour le 15 décembre 2004.

Je vous prie d'agréer, Madame, l'expression de ma considération distinguée.

Avec mes remerciements

La Directrice Générale

Michèle FROMENT-VEDRINE

Appendix b: Mandate letter to the AFSSE

COURRIER REÇU LE

06 FEV 2004

4856

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RÉPUBLIQUE FRANÇAISE

MINISTERE DE L'ECOLOGIE ET DU DEVELOPPEMENT DURABLE
Direction des études économiques et de l'évaluation environnementale

MINISTERE DE LA SANTE, DE LA FAMILLE ET DES PERSONNES HANDICAPEES
Direction générale de la santé
365/5398/27

Le Directeur Général de la Santé

Le Directeur des Etudes Economiques
et de l'Evaluation Environnementale

à

Madame la Directrice Générale de
l'Agence Française de Sécurité
Sanitaire Environnementale
27-31 Avenue du Général Leclerc-
BP320
94709 MAISONS ALFORT Cedex

Paris, le 03 FEV. 2004

Objet : Saisine de l'AFSSE concernant la téléphonie mobile et les antennes relais de type UMTS

Madame la Directrice Générale,

La téléphonie mobile est sur le point de se développer par l'utilisation d'une nouvelle technologie dénommée UMTS (Universal Mobile Telephony System). Celle-ci est notamment fondée sur une méthode de partage des fréquences différente de celle actuellement utilisée par la technologie GSM (Global System for Mobile Communication). Le déploiement de ce nouveau système de communication doit se faire sur toute la France dès 2004. L'exposition des populations est potentiellement importante et il importe donc de s'assurer des conditions de déploiement de cette nouvelle technologie.

A l'issue d'une étude fondée sur des tests effectués en laboratoires courant 2003, l'institut de recherche technologique néerlandais TNO a fait état d'effets spécifiques sur les personnes exposées à l'émission d'ondes électromagnétiques à proximité des antennes relais de type UMTS. Les personnes testées auraient fait part notamment de sensations de picotement, de maux de tête et de nausées.

Nous vous remercions pour les premiers éléments d'analyse que vous nous avez communiqués sur la validité et les conclusions de cette étude. Ils soulignent la nature controversée des résultats et suggèrent des propositions d'études complémentaires. C'est pourquoi nous vous demandons d'explorer plus avant :

- les conditions de la pertinence de telles études,
- leur faisabilité technique et financière,
- les problèmes méthodologiques et les biais de sélection dans les groupes témoins qu'il conviendrait d'éviter pour une interprétation fiable des résultats.

Sur ce dernier point, nous vous suggérons notamment de vous mettre en rapport avec l'Institut de veille sanitaire.

Nous vous prions d'agréer, Madame la Directrice Générale, l'assurance de notre considération distinguée.

Le directeur général de la santé

Professeur William DAB

Le directeur des études économiques et de l'évaluation environnementale

[illegible]

Appendix c: WHO recommendations on children

WHO Workshop on Childhood Sensitivity to EMFs

Istanbul, Turkey, 11June 2004

Working Group Research Recommendations

Chairman: Mike Repacholi

Rapporteurs: Emilie van Deventer, Leeka Kheifets, Rick Saunders

Membership:

Alastair McKinlay; Arwel Barrett; Robert Brent; Lawrie Challis; John Collins; Maria Feychting; Camelia Gabriel; Denis Henshaw; Jukka Juutilainen; Shaiela Kandel; Rob Kavet; Isabelle Lagroye; Stelian Ghelberg; Tracy Lightfoot; Gail Lundell; Gabor Mezei; Patricia McKinney; Chiyoji Ohkubo; Christof Olivier; Ludek Pekarek; Agnette Peralta; Carlos de Pozo; Eric van Rongen; Colin Roy; Tomohiro Saito; John Scholes; Joachim Schuz; Nesrin Seyhan; Riti Shimkhada; Zenon Sienkiewicz; John Swanson; Leon du Toit; Hilary Walker; Joe Wiart; Barney de Villiers; Zhengping Xu.

Introduction and General Comments

The Working Group considered research recommendations for studies relevant to the risk of adverse health effects in children from exposure to electromagnetic fields (EMFs). The issues under consideration reflected and amplified the various suggestions and proposals made by the individual presenters at the preceding WHO Workshop on Childhood Sensitivity to EMFs held in Istanbul on 9–10 June, 2004. The workshop proceedings are available in a special edition of *Bioelectromagnetics* (in press).

Particular issues included the role of extremely low frequency (ELF) magnetic fields in the development of childhood cancer and possible risks from mobile phone radiofrequency (RF) radiation, especially regarding brain cancer and cognitive function. Less emphasis was given to risks from exposure to static fields and to fields associated with security devices. However, pregnant workers are employed in retail industries with an increasing prevalence of security and identity devices, including devices for electronic article surveillance (RFID/EAS). A better understanding of the dosimetry and possible health effects for this region of the spectrum is needed, since it is not clear that extrapolation from higher and lower frequency regions is sufficient.

Separate breakout groups considered research recommendations for further epidemiological studies, laboratory studies (including those using volunteers, animals and *in vitro* techniques), and dosimetry work which were then discussed in a plenary session. The relevance of these different studies to health risks in people varies. Epidemiological studies of the distribution of disease in populations and the factors that influence this distribution provide direct information on the health of people exposed to an agent and are given the highest weighting. However, they may be affected by bias and confounding, and their observational nature makes it difficult to infer causal relationships, except when the evidence is strong. Experimental studies using volunteers can give valuable insight into the transient physiological effects of acute exposure, although for ethical reasons these studies are normally restricted to healthy people. Recommendations concerning laboratory studies using children are, of course, subject to appropriate ethical approval. Studies of animals, tissues and cell cultures are also important but are given less weight. Animal studies can often be expected to provide qualitative information regarding potential health outcomes, but the data may not be extrapolated to provide quantitative estimates of risk, largely because of differences between species. Studies carried out at the cellular level are normally used to investigate mechanisms of interaction, but are not generally taken alone as evidence of effects *in vivo*. Nevertheless, each type of study has a role to play in determining the scientific plausibility of any potential health risk.

Dosimetry provides a precise measure of the interaction of EMFs with people, and exposure assessment provides an estimate of individual and population exposure to EMFs that contributes to the assessment of the likely impact of exposure on health. Each such assessment needs to consider all sources of EMF (low and high frequencies) to which an individual or a population may be exposed.

I. General Recommendations

The Dosimetry Working Group made the following general recommendations:

- A better understanding of foetal and childhood exposure to EMFs is required, including an assessment of exposure to the high static magnetic fields encountered around magnetic resonance imaging (MRI) equipment and the lower static magnetic fields encountered in public transport vehicles, and an assessment of exposure to ELF fields, especially residential exposure from under-floor electrical heating and from transformers in apartment buildings. For RF fields, exposure assessment is particularly weak for base stations and TV and radio towers and needs further exploration. High Priority.

Rationale: This information, in combination with dosimetric modelling and an understanding of possible biological effects, is needed to assess the risk to health posed by such exposure.

- More-accurate dosimetric models of pregnant women, of foetuses at various developmental stages (neural tube closure; differentiation and organogenesis; growth) and of children are needed. In addition, an exploration of EMF microdosimetry at the cellular or subcellular levels should be supported. High Priority

Rationale: Dosimetric information regarding pregnancy and the developing foetus is lacking; this information is required for a proper health risk assessment. In addition, exploration of EMF microdosimetry may yield new insights concerning biologically relevant targets.

- Additional data on the dielectric and thermal properties of human tissues and organs at various developmental stages, including the foetal stage, is needed. High Priority

Rationale: The dielectric constant is a factor that varies with age. Foetal data could be significantly different from data on children or adults, but it may be very difficult to obtain ethical approval to acquire experimental data. Perhaps ultrasonic examinations could provide data on dimensions that may allow estimation of water content, from which dielectric constants can be derived.

II. Static Fields

Static magnetic fields were not specifically addressed at the Workshop. It was recognized, however, that there is also a need to address childhood susceptibility to static magnetic fields because of both developing technologies like magnetic levitation transportation and the ever-increasing use of magnetic resonance imaging techniques. This led to the following recommendation:

- Future laboratory studies of static magnetic fields should consider the effects of prenatal and early postnatal exposures in addition to those of adult exposure. High Priority.

Rationale: There are few studies of the effects of prenatal and early postnatal exposure, particularly to very intense magnetic fields (>1 T).

III. ELF Fields

1. Epidemiological Studies

Something of an impasse has been reached in designing studies of ELF magnetic fields and childhood leukaemia. While existing epidemiological studies show a consistent association, most of the available studies are of case-control design and are thus potentially subject to selection bias. To move forward we need innovative approaches, which might include (1) designing studies capable of evaluateing selection bias (e.g., by collecting data on magnetic fields and participation) and/or minimizing it (e.g., a cohort study), or (2) identifying large, highly exposed populations (e.g., those living in apartments next to transformers), or susceptible subgroups (e.g., previously initiated populations in which magnetic fields act as a second 'event' in carcinogenesis). In addition, two hypotheses concerning causality (contact current and melatonin) were discussed at the Workshop. All of these approaches and hypotheses pose major challenges.

- Pooled analysis of childhood cancer studies. High Priority

  Rationale: Pooled analyses of childhood leukaemia studies have been very informative. Although new studies would not fundamentally change the results of the previous pooled analyses, recent studies will add new countries and enough data to probe the results further. It might be possible to further explore the high end of the dose-response curve. Additionally, risk modifiers—for example, age—might be further explored. Brain cancer studies have shown inconsistent results; a pooled analysis of brain cancer studies may also be very informative, may inexpensively provide insight into existing data, including the possibility of selection bias, and, if appropriate (i.e., if studies are sufficiently homogeneous), may come up with the best estimate of risk.

- Further studies of ELF exposure and miscarriage. Medium Priority

  Rationale: Two recent California studies have reported an increased risk of miscarriage due to maximum levels of ELF exposure, but the studies have areas of potential weakness in study design that can be improved. First we recommend studies to identify behavioural determinants of maximum fields. Further investigation, focusing on early pregnancy loss and using improved design, would also contribute to this area.

2. Volunteer studies

These recommendations address effects for which there is some supporting evidence in studies using adults.

- Laboratory-based studies of cognition and changes in electroencephalograms (EEGs) in children exposed to ELF fields in the laboratory, if ethical approval is possible. High Priority.

  Rationale: Studies of adult volunteers and animals suggest that acute cognitive effects may occur with short-term exposures to intense fields. Such effects are very important for the development of exposure guidance (e.g., McKinlay et coll., 2004; WHO ELF Research Agenda) but there is a lack of specific data concerning field-dependent effects in children.

3. Animal studies

These recommendations focus on possible carcinogenic effects, particularly in relation to childhood leukaemia, and effects in key tissues and organs regarded as potentially susceptible to EMFs, particularly the developing central nervous system (CNS), haemopoietic (bone marrow) tissue and immune system. Experimental protocols should include prenatal and/or early postnatal exposure to EMFs.

- Further development and experimental investigation using appropriate animal models, including the use of transgenic animals (e.g., Carron et coll., 2000), which develop a disease having similarities to childhood acute lymphoblastic leukaemia. (Animal studies carried out to date have not used such models.) Experimental studies to include the effects of prenatal exposure and the combined effects of ELFs and known carcinogens. High Priority

  Rationale: The possible role of EMF exposure in childhood leukaemia development is a priority research area (e.g., AGNIR, 2001; WHO ELF Research Agenda). In addition the combined effects of ELF-EMFs and known chemical or physical carcinogens and/or mutagens have been reported in many studies (IARC, 2002).

- Studies of developmental effects of pre- and postnatal exposure to low-frequency EMFs on immune function and on the induction of minor skeletal variations. Effects of prolonged, intermittent exposure from the early postnatal period on subsequent cognitive function in animals. Medium Priority.

  Rationale: An increase in minor skeletal anomalies is the only consistent finding from a number of developmental EMF studies in mammals (e..,g Juutilainen, 2003). The immune system continues to develop postnatally; Study of the effects of ELF fields on this system is thus a useful means to evaluate them as possible immunotoxicants. Behavioural studies with immature animals provide a useful and established model for studying possible cognitive effects in children.

- Further study of possible ELF carcinogenic mechanisms, including exposure to intermittent fields and transients, both alone and in combination with known carcinogens. Low Priority.

  Rationale: The possible carcinogenicity of EMFs remains an issue of concern (e.g., IARC, 2002), although the experimental evidence for carcinogenic effects is weak. However, hypotheses such as those involving the role of signal intermittence, transients or contact currents have not been widely investigated and the possibility for co-carcinogenicity must be clarified.

4. In vitro studies

Areas requiring further ELF *in vitro* study include possible electric field and (contact) current effects on carcinogenic processes, especially pathways involved in haemopoietic cell differentiation and proliferation, and on nerve cell growth and synaptogenesis. In addition, further exploration of the possible role of melatonin in free-radical scavenging is required.

- Studies of ELF magnetic field and induced electric field effects on cell differentiation (e.g., during haemopoiesis in bone marrow) and on nerve cell growth using brain slices or cultured neurons. High Priority.

  Rationale: As in the recommended animal studies, possible effects on pre- and post-natal cellular differentiation and tissue development are a priority research area. Cell differentiation is inhibited during neoplastic progression; cell orientation and migration are both key *processes in development. The developing nervous system and bone marrow are thought to be key tissues in this respect.*

- Effect of EMF exposure on the protectiveness of physiological levels of melatonin against oxidative damage from free radicals, reactive oxygen species, etc. during haemopoiesis in foetal and postnatal tissue. Medium Priority.

  Rationale: Melatonin has been shown to be highly protective against oxidative damage to human lymphocytes in vitro (e.g., Vijayalaxami et coll., 1996, 2004) and similar damage to the brain tissue of rat foetuses in vivo (Wakatsuki et coll., 1999, 2001), possibly by increasing the concentration of known radical scavengers such as superoxidase dismutase (Okatani et coll., 2000). The possibility that EMF exposure may affect the ability of melatonin to suppress oxidative damage in foetal or postnatal tissue should be investigated.

- Further studies of possible carcinogenic mechanisms for ELF fields, particularly in combination with known carcinogens. Low Priority

  Rationale: The possible carcinogenicity of EMFs remains an issue of concern (e.g., IARC, 2002), although the experimental evidence for carcinogenic effects is weak. The combined effects of ELF-EMFs and known chemical or physical carcinogens and/or mutagens have been reported in many studies (IARC, 2002). In addition, hypotheses such as those involving the possible role of signal intermittence or transients have not been studied.

5. Dosimetry and exposure assessment

A better understanding of the prevalence of earth leakage currents and the potential consequences of exposure to contact currents in small children (e.g., when bathing), is needed. Work is in progress to examine the prevalence of contact currents in countries other than the United States (e.g., in European and Asian residential electrical systems). If exposure to contact currents is a global issue and some mechanism can be demonstrated, the model should be further examined.

- Dosimetric modelling of the interaction between induced or injected current and juvenile limbs should be undertaken, taking account of reduced surface resistance, lack of bone calcification and the presence of active marrow. High Priority.

  Rationale: The extent to which electric current flows through the bone marrow of small children as a consequence of contact which allows an earth leakage current to flow through their bodies should be further studied.

- Assess exposure to the 217-Hz nonsinusoidal magnetic fields from mobile phones. Low Priority

  Rationale: The pulsating battery current in a mobile phone generates a low-frequency nonsinusoidal magnetic field (Jokela 2004) in the vicinity of the phone. The field penetrates without any effect on the skin into tissue. Some preliminary estimates show that the resulting exposure to induced currents in the head is not much lower than the ICNIRP limit. Furthermore, it has been suggested that mobile phones are an important source of ELF exposure, particularly to bone marrow in children's hands. More detailed investigation of exposure is necessary to assess exposure quantitatively.

IV RF Fields

1. Epidemiological studies

There is little relevant epidemiology at present that examines health effects in children; the following recommendations address general health effects, including cancers in children who use mobile phones or live near base stations or radio or TV towers.

- Prospective cohort study of children mobile phone users and all health outcomes other than brain cancer (see below) but including more general health outcomes such as cognitive effects and effects on sleep quality. High Priority

  Rationale: Since many children are heavy mobile phone users and will continue to be in the future, they represent a unique population. The type of mobile use among children (e.g. text messaging), their potential biologic vulnerability and longer lifetime exposure make such a study desirable. Cognitive effects and other general health outcomes have been anecdotally reported in mobile phone users. They can be assessed in a prospective cohort study of children. A separate study of children was found necessary, as it is not possible to just extend the age range of a cohort study of adults because the outcomes have to be assessed by different methods in children and adults, and children's exposure probably differs from that of adults' (more use of pay-as-you-go SIM-cards, more frequent change of phones and operator).

- Case-control study of children mobile phone users and brain cancer. High Priority

  Rationale: Brain cancer is an important end-point to study given the location of the antenna for the phone, but it is rare in children and so this is not likely to be a feasible end-point for a cohort study.

- Nested case control studies of childhood cancer with improved exposure assessment for (1) base stations and (2) TV and radio towers. High Priority

  Rationale: There is at present a lack of information concerning health effects associated with living in close proximity to base stations or TV or radio towers. One particular difficulty is exposure assessment. Further investigation into improved measures is a critical step in better capturing exposure from these sources and in determining the feasibility of epidemiological studies of children living in the vicinity of these sources.

2. Volunteer studies

The following recommendations address effects seen in laboratory-based studies using adult volunteers.

- A laboratory-based assessment of effects of RF exposure on cognition, EEGs, and sleep in children is recommended as a part of a larger prospective cohort study (see the Epidemiology section). If ethical approval can be obtained, acute effects on cognition and EEGs should also be investigated in children exposed to RF fields in the laboratory. High Priority.

  Rationale: Cognitive effects are a priority research area in RF studies. However there is a paucity of data concerning RF effects on children (Goldstein et coll, 2003; AGNIR, 2003; WHO RF Research Agenda).

3. Animal studies

A large U.S. National Toxicology Program (NTP) rodent (both rats and mice) study is likely to be funded in the near future. The study will examine the toxicity and carcinogenicity of RF radiation characteristic of mobile phones; animals will be exposed in utero and postnatally. A full histopathology will be carried out, along with assays of endocrine levels, estrus cycling and sperm levels, urinary metabolite patterns (as indicators of physiological perturbation), haematology and genotoxicity (i.e., micronucleus frequency, DNA-strand breaks, etc.). There will be a particular focus on changes in blood-brain-barrier permeability and any concomitant neuropathology. [Tissue may be made available to other research groups; contact: Ron Melnick, e-mail: melnickr@niehs.nih.gov .]

The recommendations given below focus on the developing central nervous system, haematopoietic (bone marrow) tissue and immune system. Experimental protocols should include prenatal and/or early postnatal exposure to EMFs.

- Studies investigating the effects of prolonged exposure of immature animals to RF fields on the development and maturation of the CNS, using behavioural, morphological (e.g., synapse formation) and molecular (e.g., using gene microarrays) endpoints. High Priority.

  Rationale: Possible RF effects on children were specifically raised by the UK's Independent Expert Group on Mobile Telephones (IEGMP, 2000); the CNS was considered potentially one of the most susceptible of the various organs and tissues that continue to develop during childhood.

- Effects of prenatal exposure to RF fields on the development and maturation of the blood-brain barrier. [Note that funded work is likely to begin on this topic in the near future; see above.] High Priority

  Rationale: Possible effects on the adult blood-brain barrier and the potential for resulting neuropathology have long been a controversial issue in RF research (e.g., IEGMP, 2000; WHO RF Research Agenda). These studies should be extended to cover pre- and postnatal development of the blood-brain barrier. (In humans, this development is complete at approximately 6 months [Rodier, 2004].)

- Studies investigating the effects of prolonged exposure of immature animals to RF fields on the development of the immune system, including microglia cells (resident macrophages) and induction of autoimmunity in the brain. Medium Priority.

  Rationale: The immune system also develops during early childhood and is a critical tissue with regard to possible effects of RF exposure. Studies performed in the former USSR showed induction of autoimmunity after exposure to RF fields (Vinogradov, 1993).

4. In vitro studies

Studies of possible RF effects on carcinogenic processes, particularly effects on differentiation pathways and haemopoietic tissue, continue to be of interest. In addition, effects on nerve cell growth and synaptogenesis are considered worthy of further research. The possibility that biological tissue can somehow demodulate modulated RF signals to produce biologically significant ELF electric fields and currents has long been a controversial area. Research into this area, based on a recently proposed, very sensitive method of detection, is being funded in the UK (Challis, in press). If real, this effect could have important implications for both childhood and adult exposure. Other mechanistic studies were also recommended.

- Studies of RF effects on cell differentiation, e.g., during haemopoiesis in bone marrow, and on nerve cell growth using brain slices/cultured neurons. High Priority.

  Rationale: Cancer cells are generally locked into a rapidly dividing and relatively undifferentiated state, and the possibility that haemopoietic and/or neuronal tissue shows a *growth response to EMF exposure was considered to be an important area for further investigation.*

- Continued studies of possible mechanisms of RF interaction. Medium Priority.

  Rationale: Research hypotheses based on plausible interaction mechanisms are a key part of the design and execution of animal and epidemiological studies carried out in order to evaluate possible risks to health. There are two hypotheses that are worthy of further investigation (Challis, this issue): (1.) Whether the mechanism leading to an increase in free-radical concentrations that has been demonstrated at frequencies below 80 MHz might also apply at higher frequencies. 2. Whether the above-average temperature rises that might be expected to occur in electrically conducting regions within thermally insulated parts of the body, such as the cochlea and vestibular apparatus, are large enough to cause concern.

5. Dosimetry and exposure assessment

A key issue in this area has been the development of a personal dosimeter in order to greatly improve exposure assessment (for example, around base stations) for epidemiological studies (Wiart, in press). Recommendations were made for improved childhood exposure assessment and dosimetric and thermal modelling.

- Research is needed to document rapidly changing patterns of phone use (SMS, email, classical phone communication, etc.) and exposure of different parts of the body for children and foetuses. High priority

  Rationale: This research would be required to complement epidemiological studies. Exposure surveys (in contrast to simple source evaluations) to assess children's exposure are lacking, but urgently needed. Service providers are important sources of information regarding exposure and should be encouraged to participate in exposure surveys and epidemiological studies.

- Dosimetric models of RF energy deposition in children and foetuses, combined with appropriate models of human (childhood) thermoregulatory responses, should be developed. High priority

  Rationale: These dosimetric and thermoregulatory models are required in order to predict potential hazards associated with specific RF exposure conditions (Goldstein et coll., 2003; WHO RF Research Agenda). Dosimetric calculations and realistic modelling of exposure to the foetus under various exposure scenarios (e.g., with and without a hands-free device) are needed.

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Appendix d: Definition of EIRP

Transmission antennas are used to radiate the power that is supplied to them in various directions in space. If the antenna radiates in the same way in absolutely all directions, the antenna is termed an isotropic antenna. Although it is physically impossible to construct such an antenna, this model serves as a reference.

When one uses an actual antenna, most of its radiation is directed mainly in one direction, and one is generally interested in the flow of power (or power flux) at a distance d from the antenna in that direction. This introduces a fictional power value called EIRP (Effective or Equivalent Isotropic Radiated Power), which is the power that would need to be supplied to an isotropic antenna located in the same position as the actual antenna in order to obtain the same flow of power to the reception point (a point located at a distance d in the main direction of radiation of the actual antenna).

The EIRP is used to facilitate the calculation of this flow of power or power flux (notated ϕ) in that direction by simply dividing the EIRP by the surface area of a sphere with a radius d (centred on the transmitting antenna): $\phi = \frac{PIRE}{4\pi d^2}$.

The EIRP is expressed in Watts, and is equal to the product of the power supplied to the antenna by the antenna's gain, but one should not lose sight of the fact that it is a fictional value representing the power that would need to be supplied to an isotropic antenna. Finally, the EIRP is only valid in the main direction of radiation of the antenna under consideration.