



COST 244 bis

Biomedical Effects of Electromagnetic Fields

Final report

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Executive Summary

The Action COST244bis, "Biomedical Effects of Electromagnetic Fields" was carried out between 1996 and 2000 in response to the continued and growing concerns about possible adverse health effects of electric, magnetic or electromagnetic fields. In terms of the objectives set out in the Memorandum of Understanding of this Action, the accomplishments have been:

- to co-ordinate the research activities in different COST 244bis areas,
- to build on the co-operative/co-ordinate networks already established,
- to accelerate exchanges of scientists,
- to prepare common research protocols, etc.

The results of the Action in terms of a better understanding of biomedical effects of electromagnetic fields are derived from the ongoing research activity in Europe and elsewhere, and have been collected through these above mentioned activities. This understanding can be divided in three main domains, related to the fundamental frequency of the electromagnetic field in question: Extremely low frequencies (ELF), intermediate frequencies (IF) and high frequencies or radio frequencies (RF).

The public concern and a substantial part of the research activity was earlier focused upon ELF in public domains such as high voltage lines and household appliances and in occupational domains. During the course of this Action, the focus has largely shifted towards the RF area because of the strong development of mobile telecommunication and the increasing widespread concern that this has elicited.

Some epidemiological studies carried out in the last decades on the possible connection between ELF fields (mainly the magnetic field component) and cancer, have revealed a weak statistical association between

- situations in the vicinity of power lines and childhood leukaemia, and
- situations where strong magnetic fields occur in the occupational setting and adult leukaemia or brain tumours.

This statistical association has, however, not been confirmed by experimental investigations on animals, nor has it been supported by any mechanistic understanding based on in vitro studies. Thus, there is a considerable uncertainty whether this statistical association is due to a causal relationship between ELF magnetic field exposure and cancer development, or whether other factors in these situations are the real reasons for the observed excess occurrence of cancer. During the course of the Action, some epidemiological studies carried out in various countries have also reduced the credibility of the statistical association mentioned above. Currently, the emphasis has also shifted somewhat from cancer to other health outcomes such as neurological disorders and symptoms. Many of these issues were addressed by some COST 244bis activities, primarily the workshops held in Nimes (1997), Graz (1998), Zagreb (1998), Madrid (2000) and Munich (2000).

Concerning the possibility of health effects due to exposure to intermediate frequency fields, the research activity is currently rather limited. Some earlier results in terms of exposure situations around visual display units have not indicated effects at low level exposures. In the last few years, this frequency domain has become the object of increased attention, because of the proliferation of devices such as electronic surveillance causing substantial exposures to some occupational groups as well as members of the general public. So far, no health hazards have been identified with this practice, but some concern exists about interference with surgically implanted medical

devices such as pacemakers or defibrillators. COST 244bis workshops held in Paris (1998), Graz (1998), Southampton (1999) and Madrid (2000) partially dealt with these concerns. Several COST 244bis members also participate in ICNIRP activities that currently address some of these issues.

By and large, research into possible effects of radiofrequency fields and adverse effects have been concentrated on the possibility of effects elicited at low levels, too low to cause significant heating in the human body. In terms of mobile telecommunication, such exposures may occur due to the use of the phones. In contrast, the public's exposure in the vicinity of base station antenna is very much lower, as verified by the Short Term Mission on Base Station Antenna of the COST 244bis.

Accordingly, most research activities in Europe and elsewhere have been concentrated on the mobile phone use situation. During the course of this Action, some key elements of such research have been included in the 5th Framework Programme. As an integral part of the COST 244bis Action, an updated appraisal was obtained of the rather substantial research activity carried out so far. This research has not been able to identify any substantiated adverse health effects occurring as a result of the exposure from mobile phones. However, several areas where further biological research is warranted were pointed out. Most COST 244bis workshops dealt with different aspects of radiofrequency and mobile phone issues.

Overall, the results of the last few years research in Europe and elsewhere have not identified adverse health effects due to exposure to electromagnetic fields at the low levels occurring in most occupational or environmental settings. A number of uncertainties still exist with existing exposure situations though, and new applications of electromagnetic fields due to emerging technologies may also motivate further research activities. The European Council has recommended its Member Nations to closely follow further development, and to facilitate research at the national level.

There are situations, however, where exposures are fairly high, and where risks of well established acute effects exist. In response to this, the European Council in 1998 also advised the Member Nations to establish recommendations for limiting public exposures to electric, magnetic and electromagnetic fields in the frequency range of 0 to 300 GHz.

During the 4 years of this Action, substantial advances have been made in research and public health aspects related to electromagnetic field exposures. In a world-wide perspective, activities in Europe have been substantial and partly dominating. The Action has contributed to these activities in several ways. Tangible deliverables of the Action include:

- various specific reviews and reports emanating from the workshops, including 11 issues of the COST 244bis Newsletter
- a review and research co-ordination activities leading up to 5th Framework Programme projects,
- outcome of a Short Term Mission on public exposure to base station antenna fields and the data base established by COST244 and continued through the COST244bis Action.
- a review of research on possible health effects of mobile phones world wide and a proposal for future research, including activities under the 5th Framework Programme
- a European research network offering opportunities to form co-ordinated research efforts (which already has resulted in several actual projects), and incentives to form several national research programmes.

A. Background

COST Action 244, Biomedical Effects of Electromagnetic Fields, started 1992 and was closed in June 1996. This Action did provide an open channel for co-operation among all research groups in Europe and, as such, provided a unique form of cross-border research co-operation compared to the USA, Japan and others.

The accomplishments of the COST 244 included:

- establishment of communication channels among European researchers;
- construction of a data base of European research in the COST 244 area;
- initiation of co-ordinated research activity;
- initiation of discussion on almost all tasks identified in the MOU;
- substantial progress on co-ordinated research activities related to benchmark models for numerical and physical dosimetry.

As a consequence, the potential existed for considerable acceleration of scientific advances in the area of biomedical effects of electromagnetic fields, with complementary use of equipment, instrumentation and other laboratory resources and human potential. The COST 244 Action permitted other countries to participate on an institutional basis; it had the potential to provide a global international framework for research activities based on co-operative, rather than competitive principles.

When the COST 244 Action was closed, it was obvious that several problems concerning biomedical effects of electromagnetic fields were not solved during the period of the Action. Thus there was a need for a continuation with the aim to continue the work of the previous Action. This continuation, Action 244bis, with the same title as Action 244, started in November 1996, and its tasks were:

- to co-ordinate the research activities in different COST 244bis areas;
- to build on the co-operative/co-ordinate networks already established;
- to accelerate exchanges of scientists;
- to prepare common research protocols, etc.

Understanding the interaction of living beings with electromagnetic fields (EMF) requires knowledge of both EMF propagation and the biophysical and biochemical mechanisms of interactions. Such research has not been supported by any other European research programme (European Science Foundation, EUREKA, EU Community Programmes, etc.). Research within the COST 244 domain has been supported only by national funds. Therefore, financial support for the COST 244bis research activities has been a significant problem, especially for those activities related to pan-European co-operation and co-ordination. Examples are maintaining the network of scientific collaboration, working on the development of common research protocols and methods.

The multidisciplinary nature of research activities in the COST 244bis domain and the unusually large number of participants in the Action (from 19 COST countries) has meant that it has been a challenging task to establish effective ways of co-ordinating the diversity of research undertaken by the scientists involved in the Action. COST 244bis has made considerable progress in establishing "a way of working" for such a diverse programme, and COST 244bis has supported to build on the accomplishments already realised. This has also made this Action somewhat different from other Actions in that its objectives are rather broad and not specified to narrowly defined issues. The development of the large network is a process that has taken several years to accomplish. It should be stressed that this network provides a powerful tool to approach scientists in Europe, which should be useful for the European Commission.

The Action COST 244bis has continued to be supported under the Technical Committee for Telecommunications (TCT) umbrella because:

- the use of wireless telecommunications is expanding rapidly;
- telecommunications encompasses both the sources of and those exposed to EM fields;
- there are many occupationally exposed people working in the area of telecommunications;
- the technical and scientific aspects of the problem of EM exposure to RF fields has not been sufficiently investigated;
- exposure and technical standards relating specifically to telecommunications are currently being formulated.

B. Objectives of the Action

The GENERAL OBJECTIVES as laid down in the Memorandum of Understanding and its Technical Annex (collectively referred to below as the MoU, quotations from the MoU are given in *italics*) of the COST 244bis Action were:

- *to create European co-ordination for research in the area of EMF biomedical effects;*
- *to co-ordinate and promote national research activities at the European level;*
- *to stimulate multidisciplinary collaboration between experts in the fields of medicine, biology, electrical engineering, physics, etc.*

At the start of the COST244bis Action, few national research programmes into biomedical effects of EMF existed. In several European nations (e.g. Finland, France, Italy and the UK), such programmes have been initiated during the Action, with involvement of the Action and its members. Other examples of activities to fulfil the general objectives are creation of network (see further below under Specific Objectives), organising of workshops and short term missions.

On the basis of these general aims, some SPECIFIC OBJECTIVES mainly related to standard settings were identified in the MoU:

- *to establish a mechanism and a European network for continuously co-ordinated research in the area of biomedical effects of EM fields and interactive repercussions on the corresponding standards;*
- *to ensure that new European standards relating to the protection of the general public and occupationally exposed personnel against EM exposure have sound scientific bases;*
- *to ensure that new common European standards relating to the technical characteristics of EM sources have sound scientific bases.*

A number of research projects have been initiated between COST 244bis members, partly in response to issues raised at workshops. COST244bis has also participated in the Research Co-ordination Committee of WHO's EMF Project.

Several COST244bis members have participated in organisations involved with the development of standards (ICNIRP, TC111 of CENELEC, EU Recommendations), thus participating in activities that assure that standards have a sound scientific base. Members have also participated in WHO meetings for standards harmonisation.

Other examples of results by which the Action fulfilled these objectives are the establishment of a network that allows quick responses to demands for information about specific issues relating to biomedical effects of EMF. Other information activities include the creation of a database, a web-page and dissemination of newsletters.

SECONDARY OBJECTIVES formulated in the MoU were:

- *to support and encourage links with the EU Community Programmes in the form of "Concertation Actions" or any other form;*
- *to support and encourage any action for additional network activity, including exchanges of scientists and training at recognised "centres of excellence";*
- *to encourage further research at the national level during the transition phase to a common European standard through the better understanding of the effects and mechanisms of action of EMFs on human beings that will arise as a result of co-ordinated research in this area;*

- *to establish an ongoing research programme for epidemiological studies in the field of long-term, low-level (outside the levels addressed by exposure standards) EMF exposure at selected frequencies.*

Within the Action, a number of activities responded to these objectives. Opportunities were created enabling individual researchers to meet and plan for collaborated efforts in EMF research, e.g. projects supported by EU 5th Framework Programme. Successive cut-downs in the COST244bis annual budgets restricted, however, some activities. Thus, no training at “centres of excellence” were carried out. Some recent workshops during the Action were specifically directed towards an understanding of mechanisms of interactions (“Bioeffects of Transient EMF Exposure” in Madrid, May 2000 and “Biological EMF-Interaction Mechanisms and their Relevance to Exposure Limits”, in Munich, June 2000). Two short term missions were planned to evaluate human exposure levels, that would be useful for designing and/or evaluating epidemiological studies, one on public exposure around mobile phone base stations, and the second on a comparison of extremely low frequency magnetic field levels in residential houses between countries. Only the first of these could be carried out, partly due to budget restrictions. Collaboration with the COST259 Action “Wireless flexible personalised communication” and the WHO EMF project should also be mentioned here.

During the course of the Action, COST244bis was approached by the Commission on two occasions to perform additional tasks:

- Undertake a project entitled “Possible Health Effects Related to the Use of Radiotelephones” with the aim of formulating the needs for research into this topic within the EU 5th Framework Programme. (This is henceforth referred to as the Mobile Phone Project.)
- Program planning and participation in the “First Japan-Korea-EU Workshop on EMF Human Hazard Issue”, on invitation to the Commission from the Ministry of Posts and Telecommunications in Japan, and held in Tokyo in October 1999. In addition, COST 244bis has been asked to undertake the program planning for a follow-up meeting in Europe (also including participation of the USA).

The Programme of the Action has also been modified (extended) to meet further demands which were not explicitly formulated in the MoU. This involved increased discussion on emerging technologies and their possible impact on human exposure and health. A specific workshop on this topic was organised (“Emerging Technologies”, Southampton, November 1999). Further details of these activities are described below.

In the course of this Action, and partially in direct response to the co-ordination of research performed under the COST244bis Action, European activity in the area of biomedical effects of EMF has achieved a dominant position in the world. Active co-operation also of non-EU COST countries and others (on the Institutional principle) have also contributed to the research programme and the scientific dialogue. Thus, the results of these co-ordination and co-operation activities have accelerated the promotion of multidisciplinary approaches in EMF research.

C. The Scientific Programme of the Action

In the MoU, the description of the scientific programme was divided in two parts, one general and one specific.

General Topics

Responses to some of the general topics below are addressed in the following section on “Specific Topics”, as indicated.

- a. *Continually updating of the common database of research teams and ongoing research projects in Europe and outside Europe established in the COST 244.*
This database has formed the basis for a number of deliberations, e.g. in terms of the Mobile Phone Project (see below). This database and the web side where it is displayed forms a resource for scientists searching collaboration partners.
- b. *Critically analysing new scientific literature.*
This forms the objective of the Mobile Phone Project and all workshops carried out during the course of this Action (see below). A related database containing an evaluation of the literature is the FEMU database in Aachen, Germany (www.femu.de).
- c. *Preparing, on a regular basis, comprehensive reports assessing the progress on bioelectromagnetic research in Europe.*
This has been a continuous effort in most workshops such as Workshops 1, 3-5, 7-12. Another effort is the Mobile Phone Project report.
- d. *Identifying areas for intensified research activity in the Fifth Framework Programmes of the EU.*
Areas where further research activities were identified have been formulated in the reports from a number of workshops, especially Workshops 3, 7 and 9, as well as the Mobile Phone Project report.
- e. *Elaborating specific position statements addressed to the scientific community, the decision-makers, regulators and industry managers.*
The mechanisms by which this objective was accomplished were by the dissemination of newsletters to individuals in positions in both EU and non-EU countries.
- f. *Considering the implications of research results for standardisation activities, e.g. of CENELEC, ETSI etc., particularly in the field of wireless communications.*
This has been commented on in the proceedings from some of the workshops, see further below.

Specific Topics

The Specific Topics listed in the Memorandum of Understanding (MoU) are quoted below *in italics*, together with comments on their fulfilment, and giving reference to the specific part of the Action having dealt with each topic. The main deliverables from the Action consist of the proceedings and summaries from 12 workshops organised within the Action.

In addition, two workshops were based on special requests:

- The Forum on Future European Research on Mobile Communications and Health in Bordeaux, France on April 1999 (organised by COST244bis, but on special request and separate budget from the European Commission).
- Secondly, COST244bis participated in the First Japan-Korea-EU Workshop on “EMF Human Hazard Issue” in Tokyo, Japan in October, 1999.

As these two workshops were made possible due to the existence of the Action, they are included here. In addition, a Short Term Mission was set up, to collect and co-ordinate data on human exposure in the vicinity of base station antenna for mobile telecommunication.

1. Human Epidemiology

To promote and/or coordinate international studies of particular importance for assessment of health risks from environmental or occupational exposures. For example: mobile phone users, residents living close to RF transmission stations, high voltage power lines or powerful radar stations, telecommunications personnel, resistance welders, plastic welding workers, transmitter factory workers. Studies on mobile phone users have particularly been encouraged as such studies presently are lacking.

Workshop 5 (Zagreb, 1998) dealt with methods for exposure assessments in epidemiological studies of radiofrequency fields, and resultant exposure levels both for occupational situations such as plastic welders and mobile phone usage situations. A Short Term Mission was set up to co-ordinate existing data on public exposure near RF transmitters (especially mobile telecommunication base station antenna). Exposure assessments due to some emerging technologies (induction cooking, anti-theft devices) were discussed in workshop 3 (Paris, 1998) and workshop 9 (Southampton, 1999).

In Workshop 1 (Nîmes, 1997), an overview of results of epidemiological studies on primarily low frequency fields was presented, and the need to co-ordinate these with experimental studies aimed at elucidating possible mechanisms was emphasised. In Workshop 4 (Graz, 1998) and in Workshop 7 (Bordeaux, 1999), some epidemiological results pertaining to mobile phone users as well as high occupational exposure to radiofrequency fields such as radar personnel were presented.

2. Occupational Medicine

- 2.1 *To promote and/or co-ordinate international studies of particular importance for assessments of health risks and morbidity of workers exposed occupationally to high level EMFs. For example: telecommunications personnel, resistance welders, radar service personnel, high power line workers, workers using sewing machines, transmitter factory workers.*

Clinical and case studies of highly exposed workers were discussed at Workshop 1 (Nîmes, 1997). The presentation focused on some special characteristics of such cases, and ways to improve safety routines to avoid future accidents. At Workshop 4 (Graz, 1998), this topic was again taken up, but then with the focus on cases of electromagnetic hypersensitivity. Here, several suggestions for the adequate handling of such cases by the medical profession were presented.

- 2.2. *To organise a network which would collect details of all cases of accidents and diseases assumed to be related to exposure to EMF.*

The relative scarcity of case reports on highly exposed workers makes it advisable to co-ordinate data on these on a European basis. An existing data-base in France was presented at Workshop 1 (Nîmes, 1997), with the purpose of expanding this to a European base for community value on prevention of work accidents.

To promote a better assessment of this risk, a database about practical problems linked to the use of EMF in industry was developed, with the financial support of INRS (French National Research and Safety Institute).

This data base is implemented by a network including

- occupational medicine Departments located in University Hospitals
- occupational doctors working in industrial environment
- safety engineers
- the department of Medical Biophysics at the University Hospital in Nîmes, France.

This network allows access to medical cases, and to information about the real problems linked to EMF exposures or the concerns they induce.

Data are checked for (see Appendix 17):

- **acute exposure of workers**, in which case are noted: physical parameters of EMF exposure, characteristics of emitters, industry using these devices, clinical complaints, medical observations of exposed workers and the results of possible medico technical examinations, the evolution of observed symptoms.
- **the concerns in relation with chronic exposure to EMF**, for example possibility for a pregnant woman to work near to an MRI device or an RF welding machine, EMF interference with active implants, etc.

From this data base, it will be possible to establish statistical data to follow the development of EMF risk in relation to industrial development of EMF use.

When the tuning phase are finished in France, it seems to interesting to extend the checking of the data to other European countries. More information can be found at the web-site (www.inrs.fr).

3. Hypersensitivity to Electricity

- 3.1. *Analysis and assessment of possible hypersensitive reactions to EMF exposure with emphasis on the borderline area between psychosomatic and somatic symptomatology.*

This topic was dealt with at Workshop 4 (Graz, 1998), where clinical, etiological and sociological aspects were considered. A shorter review of the topic was also presented at Workshop 1 (Nîmes, 1997). Overall, individuals with sometimes severe health problems which they attribute to (weak) sources of EMF undoubtedly exist, but it remains an open question whether these are directly linked to EMF, to other physical factors, or to psychosomatic reactions related to stress and worry. The importance and the variation of risk perception related to EMF was generally addresses at Workshop 9 (Southampton, 1999).

4. Design, Performance and Evaluation of Experiments

- 4.1. *Design and quality control of laboratory exposure systems*
At the end of COST 244, general guidelines were sought for the two frequency ranges, ELF and RF, both in vivo and in vitro. For COST 244bis the progress in exposure system designs has been assessed and incorporated into standardised designs.

Workshop 6 (Zurich, 1999) dealt at some length with the design of exposure systems for in vitro, in vivo and human laboratory experiments. A number of recommendations were made concerning the incident signal parameters, the delivery system, and the aim and ability to obtain homogenous exposure, appropriate dosimetry and control over environmental parameters. Still, major differences in many studies as to exposure systems make comparisons and replication attempts difficult. These requirements were summarised at Workshop 7 (Bordeaux, 1999), and briefly in terms of animal studies, also at Workshop 1 (Nîmes, 1997).

4.2. *In vitro* experiments

Rationale for the choice of biological models and exposure conditions. Evaluation of published results and extrapolation to animal investigations.

A review of in vitro studies relevant to RF and mobile telecommunication was presented at Workshop 7 (Bordeaux, 1999). A brief summary was also presented at Workshop 1 (Nîmes, 1997), where also the need to perform further experiments in order to obtain more data on possible interaction mechanisms was pointed out (see further below and Workshops 10 and 11). Some presentations pertinent to mobile telephone use were also given at Workshop 8 (Tokyo, 1999).

4.3. *Animal experiments*

Rationale for the choice of biological models and exposure conditions. Analysis of possible consequences of the experimental results on human health and on existing safety standards.

A review of animal (in vivo) studies relevant to RF and mobile telecommunication was presented at Workshop 7 (Bordeaux, 1999), both in terms of cancer and non-cancer effects. A review of the limited existing data on intermediate frequencies (1 kHz – 3 MHz) was given at Workshop 3 (Paris, 1998). Some presentations pertinent to mobile telephone use were also given at Workshop 8 (Tokyo, 1999).

4.4. *Human studies*

Rationale for the choice of biological models and exposure conditions. Analysis of possible consequences of the experimental results on human health and on existing safety standards.

An outlook on needed human experimental studies relevant to RF and mobile telecommunication was presented at Workshop 7 (Bordeaux, 1999). Several presentations on the results of human experimental studies were given at Workshop 4 (Graz, 1998), both related to cases of electromagnetic hypersensitivity and to normal subjects, and covering different frequency ranges. Some outcomes under study were symptoms, EEG recordings in awake subjects, and sleep parameters. The possible implications of such studies for standards were discussed both at Workshop 3 (Paris, 1997) and Workshop 4 (Graz, 1998). Some presentations pertinent to mobile telephone use were also given at Workshop 8 (Tokyo, 1999).

4.5. *Medical applications*

EMF exposure bioeffects related to medical applications. For example: cell differentiation and EMF exposure in bone and soft tissue repair.

A review of these kind of applications were presented and discussed at Workshop 12 (Bled, 2000), where basically four kinds of topics were brought up: Bone healing, electroporation and electrochemotherapy, nervous system recording and stimulation as well as tissue and nerve regeneration.

5. Interaction Mechanisms leading to Biological Effects

- 5.1. *Design of benchmark experiments, which should be reproduced by independent groups, with the goal of addressing specific interaction mechanisms under defined exposure conditions and of characterising them in a quantitative fashion.*

At Workshop 10 (Madrid, 2000) and Workshop 11 (Munich, 2000), detailed discussion of various experimental results in terms of possible interaction mechanisms occurred. (The design of e.g. in vitro studies in general has already been described (Workshop 5, Zagreb, 1998).

- 5.2. *Development of theoretical models of interaction mechanisms with some predictive ability to better explain and design experiments.*

Such theoretical models were presented at Workshop 7 (Bordeaux, 1999) and at Workshop 10 (Madrid, 2000). A limited discussion in terms of possible implications for standards occurred at Workshop 3 (Paris, 1998) and Workshop 11 (Munich, 2000).

6. Experimental and Numerical Dosimetry

This topic concerns fundamental aspects on research on biomedical effects of EMF, namely the scientific assessment of electromagnetic field distribution in the exposed subject. Data obtained by numerical simulation or experimental measurements support the formulation of reference levels as basis for protection guidelines for compliance evaluations. Great effort has been spent on comparing the results of different numerical techniques as well as comparisons between numerical and experimental results. This was reported on at Workshop 2 (Trento, 1997).

- 6.1. *Analysis of the reported biological effects with respect to the improvement of quantitative strategies for human exposure assessment.*

The limited data existing on verified biological effects have largely precluded more detailed deliberations. Nevertheless, some discussions took part e.g. at Workshop 10 (Madrid, 2000) concerning low frequency fields.

- 6.2. *Publish the database of dielectric properties of human tissues and extend it in terms of frequency and tissue types.*

Such data formed the basis of substantial discussions at Workshop 2 (Trento, 1997) and Workshop 6 (Zurich, 1999). Data have also been presented by Camelia Gabriel on the web. (<http://www.radio.fer.hr/cost244>)

Some members of the COST 244bis Action have also participated in the International EMF Dosimetry Handbook Project.

- 6.3. *To characterize the sources as radiating elements and develop simulations of the EM sources.*

Some results relevant to this were presented at Workshop 2 (Trento, 1997). Such fields are now ...< xxx text will come soon from Guglielmo d'Inzeo >.

- 6.4. *Ongoing comparison of different modelling techniques for numerical dosimetric assessment (FDTD, FEM, MoM, MMP, impedance methods, etc).*

A number of presentations on details of e.g. FDTD and other methods were given at Workshop 2 (Trento, 1997).

- 6.5. *To evaluate canonical problems more complex than those considered for us a in software validation and in the experimental assessment of exposure in order to obtain a more complete evaluation of fields inside the human body, especially the head and torso.*

Various results on e.g. SAR calculations in more refined models and further possible developments were discussed at Workshop 2 (Trento, 1997), and at Workshop 8 (Tokyo, 1999).

- 6.6. *To define reference numerical and physical models of the human body based on detailed anatomical data against which new instrumentation and modelling techniques can be tested.*

The need for such models was briefly discussed in general in Workshop 1 (Nîmes, 1997), also in relation to various methods for field exposure assessments. Some results and details were discussed at Workshop 2 (Trento, 1997).

This also forms an essential aim of the International EMF Dosimetry Handbook Project, with participation of members of this Action.

- 6.7. *To define worst case scenarios for assessment of EM exposure with respect to human exposure standards.*

Measurement methods for exposure assessment and compliance issues were discussed at several workshops; at Workshop 2 (Trento, 1997) and Workshop 5 (Zagreb, 1998) for mobile telephones and other radiofrequency field sources, at Workshop 3 (Paris, 1998) and Workshop 9 (Southampton, 1999) for low and intermediate frequencies. Measurement methods for transients were discussed at Workshop 10 (Madrid, 2000).

Exposure situations involving intermediate frequencies were reviewed at Workshop 3 (Paris, 1998). It was generally understood that while such sources are at present rather limited (apart from those around visual display unit equipment), the potential for such exposures is increasing. For radiofrequency fields, exposure surveys were reviewed at Workshop 5 (Zagreb, 1998) and Workshop 9 (Southampton, 1999), and have also been the topic of a Short Term Mission. Some data on exposure to transients were described at Workshop 10 (Madrid, 2000), including their relevance to standards.

To further the development of experimental and numerical dosimetry, the CEPHOS project was founded within the Fourth European Framework Programme, (October 1997 – October 1999). The technical objectives of this project were the following.

- Development and maintenance of a database on literature and standards referring to dosimetry and exposure problems.
- Design and study of canonical situations to be analysed both numerically and experimentally in order to assess the limits and uncertainties of the two approaches.
- Development of numerical and experimental phantoms in order to assess the human exposure to actual mobile terminals in realistic conditions.

- Definition of a procedure to test mobile phones in order to assess their compliance with reference to safety guidelines.

In addition a project under EUREKA called SARSYS also undertook research in measurement to mobile communications fields. This collaborative project was made up of three teams, one each from Switzerland, Belgium and UK, who have made contact within the action. They have contributed to the measurement standards, and are planning further work.

7. Emerging technology

During the Action, it was made apparent that further efforts were needed to characterise emerging technology and what changes these could mean for human exposure. Although human exposure is described under the specific topic of dosimetry, it was felt better to describe it as a special category below.

Reviews of various emerging technologies that may have repercussions in terms of occupational and general exposure levels were given at Workshop 3 (Paris, 1998) and at Workshop 9 (Southampton, 1999). While the former was directed specifically towards intermediate frequencies, the latter took on a more global perspective.

In Workshop 12 (Bled, 2000) future applications of magnetic fields were discussed, like transcranial brain stimulation, nerve regeneration and electrochemotherapy.

D. Organization and Timetable

The organisational framework of the COST 244 was implemented for the Management Committee (MC) activities in the COST 244bis with minor modifications appearing during the course of the Action. This includes the three Horizontal Working Groups (WGs):

- WG 1: Epidemiology and Human Health Effects,
- WG 2: Basic Research, and
- WG 3: Systems and Applications Engineering.

and three Vertical Co-ordinators:

- RFC: Mobile Communication or Radio Frequencies Co-ordinator,
- IFC: Intermediate Frequencies Co-ordinator, and
- LFC: Low Frequencies Co-ordinator.

Besides the MC Chairman, two vice-chairs were elected. These three people, together with the Chairmen of the three Working Groups, the three Vertical Co-ordinators and two members at large have constituted the Steering Group of the Action. The Steering Group has had one full day meeting every year as well as short meetings in connection with the Management Committee Meetings (MCMs).

The Management Committee (MC) met three times per year in 1997-1999 and two meetings in 2000. Because of the multidisciplinary of the COST 244bis research, each nominated COST 244bis National Co-ordinator has been responsible for the selection of the most appropriate participants for each particular meeting. The MC is responsible for the co-ordination of all activities described in the MoU (Memorandum of Understanding and its Technical Annex), for fostering co-operation and communication with other research programmes, and for activities and general science policy within COST 244bis Action.

In parallel with MCMs, workshops were usually organised. Only one MCM was held without a parallel workshop. This MCM, the last of the year 1999, was held to discuss future activities and was scheduled to take two days, leaving no time for a workshop.

The Technical Secretariat was responsible for the preparation of meeting documents and reports, as well as annual reports to TCT, administration of financial support to workshops, etc.

E. Workshops and other Activities

Organisation of workshops

The main visible activity by which this Action fulfilled its goals is the organisation and running workshops on the workshop topics. An overall strategy for the design of COST244bis workshops was discussed at the MCM in Nîmes, and agreed upon at the MCM in Trento. During the period of the Action (1997-2000), 11 workshops were arranged, generally structured as two-day meetings, with invited speakers giving overviews of specific topics within the theme of the workshop, allowing ample time for discussion and, as appropriate, formulation of commentaries or position papers. The key speakers at the workshops were largely derived from the Action network, but additional experts from outside Europe were also invited.

The COST 244bis Workshops are listed in Table 1, in which details of topics, locations and dates, the working groups and the frequency ranges relevant for the workshop are given. The column headed "MoU Topic" relates the subjects of the workshop to the relevant section in the Technical Annex of the MoU.

In addition, COST244bis participated in the First Japan-Korea-EU Workshop and Task Group Meeting on EMF Human Hazard Issue (Tokyo, October 1999). The seventh workshop, "Forum on Future European Research on Mobile Communications and Health", was arranged in conjunction with the special Project on "Possible Health Effects Related to the Use of Radiotelephones".

The tangible deliverables from each workshop are

- Proceedings, containing the text of the invited speakers as well as discussions and comments. Some of these proceedings are available from the COST244bis Secretariat and the Action Web-site (<http://www.radio.fer.hr>).
- A rapporteur's report, printed in the COST244bis Newsletter. Some overall conclusions were also formulated from several workshops, and they have generally been included in this report.

In Appendix 1–12, a short description of each workshop is given. Comments on the relationship and fulfilment of each Action Topic have already been presented above. A full report of each workshop (usually a Proceeding) can be found on the Action Web-site.

Within the flexibility of the Management Committee mandate, COST 244 bis has maintained an open invitation for participation in its activities to all countries and institutes that share a mutual scientific interest.

Concerning the Workshops, COST 244 bis has kept in mind essential definition of it. Therefore, the Workshops have been tightly focused on specific topics. Scientific contributions to the Workshops have been selected through peer review. Every effort was made to ensure that the Workshop presentations were published in the form of Proceedings prior to each workshop since they were meant to be working documents for the workshop.

Through co-operation with other European programmes, actions, organisations and bodies, COST 244bis obtained additional financial support for the Workshops, as well as for other activities.

Table 1. List of Workshops

Workshop	Location	Year/month	Relevant for		
			MoU topic	WG *	frequency
1. Electromagnetic Fields in Occupational Medicine	Nîmes (FR)	1997 / 09	1, 2.1-2, 3, 4.1-2, 6.6,	1	all
2. Survey of Canonical Problems in Mobile Communications	Trento (IT)	1997 / 12	6.2-7	3	RF
3. Biomedical Effects of Electromagnetic Fields in the Intermediate Frequency Range	Paris (FR)	1998 / 04	1, 4.3-4, 5.2, 6.7, 7	all	Intermediate
4. Electromagnetic Fields and Non-specific Health Symptoms	Graz (AT)	1998 / 09	1, 2.1, 3, 4.4	1	all
5. RF Exposure Assessments in Epidemiological Studies	Zagreb (HR)	1998 / 11	1, 5.1, 6.7	1, 3	RF
6. Exposure Systems and Their Dosimetry	Zurich (CH)	1999 / 02	4.1, 6.2,	2, 3	all
7. Forum on Future European Research on Mobile Communications and Health	Bordeaux (FR)	1999 / 04	1, 4.1-4, 5.2,	all	RF
8. EMF Human Hazard Issue	Tokyo (JP)	1999 / 10	4.2-4, 6.5	all	RF
9. Emerging Technologies	Southampton (GB)	1999 / 11	1, 3, 6.7, 7	1, 3	all
10. Bioeffects of Transient EMF Exposure	Madrid (ES)	2000 / 05	5.1-2, 6.1, 6.7	2, 3	all
11. Biological EMF-Interaction Mechanisms and Their Relevance to Exposure Limits	Munich (DE)	2000 / 06	5.1-2	2	all
12. Biomedical Applications	Bled (SI)	2000 / 10	4.5, 7	1	all

*) WG (Working Groups):

- WG 1: Epidemiology and Human Health Effects,
- WG 2: Basic Research, and
- WG 3: Systems and Applications Engineering.

The Mobile Phone Project

In 1998, COST 244bis received a special task from the European Commission to analyse the world wide scientific knowledge about possible health effects related to the use of radiotelephones and thereafter make recommendations for future European research within the Fifth Framework for Research and Development. This study was performed during 1998 and 1999. A special Forum was organised in Bordeaux in April 1999 in order to facilitate co-ordination of research project proposals for the EU Fifth Framework Programme. As a result, some such collaboration projects have been incorporated in the 5th Framework Programme. This Forum also made an opportunity for a larger group of scientist to meet and discuss together. The final report was presented to the Commission by the end of September 1999.

Short Term Mission on Mobile Communication Base Station Antennas

This Short Term Mission on exposure to electromagnetic fields around base station antennas was performed in order to collect available data on the public exposure to electromagnetic fields due to base station antennas for mobile telecommunication. Data from measurements performed in Austria, Belgium, France, Germany, Hungary and Sweden were collected and compared. Overall, a large variation in measured exposure levels was found, due to differences in measurement techniques as well as differences that originate in both spatial and temporal variations of the signal strengths. Thus, the lack of prior co-ordination in performing such measurements makes detailed comparisons between countries difficult. Despite such variations, it was found that the exposure levels to radiofrequency fields around base stations in locations with public access were invariably substantially lower than the recommended levels issued by the European Union by several orders of magnitude.

International collaboration

The European Commission was invited by the Japanese government (the Ministry of Posts and Telecommunications) to a Japan-Korea-Europe Joint Meeting on "EMF Human Health Hazards". The Commission asked COST 244bis to provide a delegation of experts for this occasion. A group of six scientists from COST 244bis participated, together with one official from the Commission. At the meeting it was decided that a follow-up meeting should be organised by the Commission during 2000. COST 244bis Action has been asked by the Commission to participate in the organisation of such a meeting in Europe, to which authorities in USA also should be invited, scheduled for 2001.

The COST Action 259 ("Wireless Flexible Personalised Communications") has approached this Action in order to initiate some collaboration. As a result, five members of COST244bis participated on the COST 259 meeting in Bergen in 1999 for further discussions.

COST 244bis has participated in the WHO EMF Project with representatives attending annual meetings of the Advisory Committee. COST244bis Action members have also participated in the various conferences and workshops organised by the Research Co-ordination Committee of the WHO EMF project in collaboration with the International Commission on Non-Ionising Radiation Protection (ICNIRP). The most recent example is the meeting on radiofrequency fields held in Erice, Italy in November 1999: "Biological Effects, Health Consequences and Standards for Pulsed Radiofrequency Fields".

Some participants in the COST244bis Action do currently serve as members of the International Commission on Non-Ionising Radiation Protection (ICNIRP). This has enabled some co-ordination and cross-fertilisation of activities, notably in the fields of intermediate frequencies, where more concerted ICNIRP activities has followed the initial initiatives of the Action. (For example, a joint ICNIRP/WHO meeting on intermediate frequencies held in Maastricht in June 1999 followed the COST244bis meeting on the same subject in Paris 1998. An ICNIRP workshop in Helsinki on anti-theft and similar devices in September 2000 followed the Action meeting on emerging technologies held in Southampton in 1999.) At the same time, the COST 244bis Action has in many respects drawn from the expertise and experience gathered by the ICNIRP. It should be mentioned that European members of ICNIRP (some of whom also actively participate in the COST244bis Action) formed the task group for DG V in formulating the European Council

recommendation for limiting public exposure to electric, magnetic and electromagnetic fields in the frequency range of 0 to 300 GHz.

Members of the Action also participate in other standard-setting organisations such as CENELEC (the Technical Committee 211 "Human Exposure to Electromagnetic Fields" and especially its Working Group 1 on product standards for mobile communication equipment). In this context, it should be mentioned that there is an ongoing process of harmonisation of guidelines and standards world wide, partially within the WHO EMF project, and partially in direct contacts between different organisations such as CENELEC and IEEE, with COST 244bis members actively participating.

One of the deliverables of this international collaboration and participation in meetings is the incorporation of the knowledge derived from those in the overall assessment of biomedical effects of electromagnetic fields performed by this Action, presented below under "Conclusions" and further elaborated e.g. in the Mobile Phone Project.

Initiation and co-ordination of research

At the onset of the COST244bis Action, formalised national research programmes concerning possible health effects of electromagnetic fields existed only in Germany (organised by the FgF – Forschungsgemeinschaft Funk) and Finland (funded by Tekes – the Technical Development Center). These programmes contained several sub-projects focused to clarify potential health effects of exposure to RF fields emitted by mobile phones.

The Finnish national programme under the COST244bis Action is called "Electromagnetic fields from mobile phones as a possible health risk". The total budget is 1.2 million euros covering six sub-projects during the years 1998-2000. The topics include various research items from in vitro tests and in vivo cancer models to human experimental and epidemiological studies.

During the Action, such national programmes have been initiated in several member countries, in some cases in direct and explicitly stated response to the existence of the Action (Italy, France). In other national programmes, the COST 244bis Action has served to co-ordinate these national activities on a European basis.

In France, the research community greatly expanded its activity in topics covered by COST 244bis. New research groups have started to work with support from public and private funding. This served as a basis for launching the COMOBIO programme (1999–2000, 2 million euros), that addresses issues related to dosimetry of mobile telephony and possible biological effects (human and animal non-cancer models).

<xxx Gerd Friedrich and Guglielmo d'Inzeo will give short descriptions of other national programs>

A major research programme in mobile communications is planned in the UK following the recommendations of the "Stewart Report" on mobile phones and health (www.iegmp.org.uk). This programme will be looking to co-ordinate its activity through the existing COST 244 network.

Substantial research efforts are also performed in many other European, even if formalised national programmes have not been launched. Information about ongoing research in some countries is found in Annex 16. As can be seen, such projects are funded by a variety of sources

– European, national as well as industrial, and are performed at various universities, national institutes as well as industry. Several examples of co-operative project involving different European nations, both within and outside of the 5th Framework Programme. Throughout the Action, several opportunities have existed for formation of international collaboration of research at workshops etc – which has resulted in some joint research projects.

In the data base of the WHO EMF project, 466 studies were found (September 2000). It can be seen that research projects in Europe constitute some 50% of those projects world wide that have been reported in this data base.

Data-base, newsletters and other methods of dissemination of information

At the onset of the previous Action (COST244), a database on research projects in member countries was established. This has been periodically updated through information provided by the national research groups to the COST 244bis Technical Secretariat, and a final update covering the time of the COST244bis Action is currently in progress. For the different member countries, the database contains brief information about past and current scientific research projects, as well as contact information about the principal investigator. This database can be reached through the COST244bis Action web-site (www.radio.fer.hr).

The Action has published 11 newsletters during the period of 1997–2000. In principle, each workshop has been followed by a newsletter, which provided summaries from the workshop as well as a report from the MCM. Special newsletters (number 7 and 8) presented reports from the Forum in Bordeaux and the Japan-Korea-Europe Joint Meeting, respectively. These newsletter can be found on the COST 244bis web-site, and has also been disseminated through a mailing list, currently containing some 300 scientists and national authorities world-wide.

Proceedings from the workshops are obtainable from the COST 244bis Secretariat (see above). Reference to the COST244bis Action and some proceedings can also be found on the WHO EMF Project web-site.

Members of the Action have participated in European Parliament meetings in order to clarify issues of possible health effects of electromagnetic fields. Some members were also exhaustively consulted in the Report on Health Effects of Electromagnetic Fields, which was submitted to the STOA (Scientific and Technology Options Assessment) of the European Parliament in June 2000 (cf. text of this report on the Web site of COST 244bis).

Conclusions and information material produced by the COST 244bis Action have been used on various occasions in public discussions and risk communication activities, even if statistics on such use are – by its very nature – difficult to ascertain. Likewise, it is in our opinion likely that the existence as such of the COST 244bis Action has been used as an argument for the responsibility of the European community to the health issues that have been raised in connection with exposure to electromagnetic fields.

F. Conclusions

The results of the Action COST 244bis in terms of a better understanding of biomedical effects of electromagnetic fields (EMFs) are derived from the ongoing research activity in Europe and elsewhere. Relevant research results and issues have been collected through the activities outlined in the Objectives and the Scientific Programme of the Memorandum of Understanding of COST 244bis.

In order to summarise the overall results of several years of research relevant to the possibility of adverse human health effects due to EMF exposure, it is necessary to separate the field into several categories. One major reason for this is that results from one of these categories (e.g. a frequency range) can not be immediately extrapolated into another – such extrapolation would often require a similarity in the responsible interaction mechanisms involved, or at least a thorough understanding of such mechanisms. A central delineation is therefore to separate the possibility of effects at extremely low frequency fields, at intermediate frequencies, at frequencies used by mobile telephony and at other frequencies, as well as various broadband applications. The issue of electromagnetic hypersensitivity – being unclear as to relevant EMF characteristics – is treated separately. Furthermore, most results (at lower frequencies) are directed towards the magnetic field component, not the electric field component.

Most of the current concern – and also of the scientific investigations currently ongoing – is directed towards the possibility of effect occurring at commonly existing exposure levels encountered for prolonged periods of time (“chronic exposure”). There are situations, however, where exposures are fairly high, and where acute effects due to this exposure have been identified and established. In order to promote public health and wellbeing on the European level, the European Council advised the Member Nations (in 1998) to establish recommendations for limiting public exposures to electric, magnetic and electromagnetic fields in the frequency range of 0 Hz to 300 GHz (Council of the European Union: Council Recommendation on the limitation of exposure of the general public to electromagnetic fields 0 Hz – 300 GHz. Document 8550/99, 5 July 1999, Brussels).

For low exposure levels (below these recommendations) of extremely low frequency magnetic fields (ELF-B), the most intriguing evidence has been derived from epidemiological studies. A large number of epidemiological studies have been carried out in the last decades on the possible connection between ELF fields (mainly the magnetic field component) and cancer. Some of them have revealed a weak statistical association between situations in the vicinity of power lines and childhood leukaemia, while others have found such associations between occupational situations where strong magnetic fields occur and adult leukaemia or brain tumours. During the course of the Action, some epidemiological studies carried out in various countries have, however, reduced the credibility of these statistical associations. A few additional studies have also suggested the possibility of weak associations between electric and magnetic fields and some other adverse health outcomes such as heart disease, neurological disorders, symptoms or depression. These latter studies, however, are currently limited and the results are far from consistent. In contrast to the cancer studies, there is an inability to draw any conclusion about a statistical association between these outcomes and electromagnetic field exposures.

However, it is currently not clear whether these results represent a causal relationship, or spurious findings due to other factors, since experimental studies, while diverse, have not been able to verify these findings. In addition, since the interaction mechanism(s) that would be responsible for such a relationship at these levels remain essentially unknown, the credibility of a causal

relationship between cancer development and exposure to low level, low frequency magnetic fields remain rather limited. Overall, exposure assessment still remains one of the major difficulties of epidemiological studies of EMF, even though substantial improvements have been made in the last few years. In recent years, the research efforts directed towards these issues have been reduced with much of the resources being redirected towards mobile telephony issues.

For **radiofrequency fields** emanating from mobile telephone systems (hand held phones and base stations), a substantial body of data has emerged in the last few years. Most research activities in Europe and elsewhere on radiofrequency fields and biological effects have lately been concentrated on the mobile phone use situation. During the course of this Action, some key elements of such research have been included in the 5th Framework Programme. As an integral part of this Action, an updated appraisal was obtained of the rather substantial research activity carried out so far. By and large, these data do not suggest the existence of adverse health effects at the low levels (non-thermal levels) encountered while using a mobile phone. (This appear even less likely at the much lower levels encountered at positions around base station antennas accessible to the public – see the outcome of the Short Term Mission). A few uncertain indications to the contrary, some suggestions of possible biological effects and the fact that some areas have not yet been adequately investigated nevertheless motivate, however, further substantial research efforts. So far, few reliable epidemiological investigations on long-term effects exist and the evolution of the technology is such that the value of such studies may be limited, especially if they turn out to be non-positive.

For **intermediate frequencies**, only limited biological and epidemiological data exist – partly in response to the discussion of a decade ago on visual display units. Evaluations of emerging issues are therefore largely based on extrapolation from other frequency regions, a shortcoming discussed at several workshops within this Action. In the last few years, this frequency domain has become the object of increased attention, because of the proliferation of devices such as electronic surveillance causing substantial exposures to some occupational groups as well as members of the general public. So far, no health hazards have been identified with this practice, but some concerns appear to exist about interference with surgically implanted medical devices such as pacemakers or defibrillators.

In terms of **electromagnetic hypersensitivity**, it is currently not clear whether the health reactions of these people that have been observed in some countries are causally related to the fields, as so far no study has been able to demonstrate such a link. Further research activity on this issue has at least in part been redirected towards other possible factors causing these problems.

Overall, the results of the last few years research in Europe and elsewhere have not identified and established adverse health effects due to exposure to electromagnetic fields at the low levels occurring in most occupational or environmental settings. A number of uncertainties still exist with existing exposure situations though, and new applications of electromagnetic fields due to emerging technologies may also motivate further research activities.

In conclusion, it is our understanding that the COST 244bis Action “Biomedical Effects of Electromagnetic Fields” have formed an integral and sometimes influential part of the ongoing research effort of these issues, at national, community and international levels.

G. Outlook for the Future

Judging from developments around the overall topic of “Biomedical Effects of Electromagnetic Fields” during the course of this Action, it is difficult to envision a clear end to the concern about electromagnetic fields and possible health effects. To the contrary, concern and the concomitant need for further research is likely to remain important issues within the European Community for an extended period in time.

This is due to (at least) two different circumstances:

- the fact that substantial gaps exist in our current understanding of biomedical effects of electromagnetic fields, especially in terms of possible interactions at very low levels, and
- the fast and increasing pace of change in our use of technology, perhaps currently manifested especially in relation to different forms of telecommunication.

Due to the latter, there is an ongoing need to examine these and other “emerging technologies”, in order to determine whether these can be evaluated by the currently available data base, or whether these emissions requires additional research efforts. An urgent example is the launch of the “third generation of mobile phones” (UMTS), which can be expected to cause additional concerns and raise questions (indeed, this has already begun in some countries, even before the actual launch of the system).

The value of this COST 244bis Action may, seen in this perspective, lie not only in the information derived from it (which is summarised above), but also in the network it has created among European scientists involved in this research. The further development of national programmes may also be dependent on such a functional network for co-ordination and co-operation. Because the network created by this Action has developed into a valuable asset in terms of its recognised input into the issue, its output of valuable information and its independence, we foresee a further need on the European level for such a network. The European Council has also recommended its Member Nations to closely follow further development, and to facilitate research at the national level.