SURVEY
OF
ELECTROMAGNETIC
FIELD LEVELS
IN
CANADIAN HOUSING

Planetary Association for Clean Energy, Inc.
for
Canada Mortgage and Housing Corporation
OTTAWA
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Disclaimer

A study "Survey of Electromagnetic Field Levels in Canadian Housing" was commissioned by Canada Mortgage and Housing Corporation (CMHC) under Part IX of the National Housing Act.

CMHC has made the draft report accessible through the Canadian Housing Information Centre. The reader is advised however that the analysis, interpretations and recommendations of this draft report are those of the consultant that performed the study and do not reflect the views of CMHC. This draft report was submitted by the consultant but has not been finalized to incorporate comments received from external and CMHC technical reviewers. Also it is to be noted that the study is dated, and therefore may not represent the current state of knowledge on this topic.

CMHC assumes no responsibility whatsoever for the information, analysis, conclusions and recommendations contained in the report or for the use by any third party of the information therein.

Survey of Electromagnetic Field Levels in Canadian Housing

EXECUTIVE SUMMARY

This survey was conducted with a small but rich sample representative of housing across Canada. The comprehensive protocol applied is amenable to the development of useful information. It is also compatible with comparable exercises done or projected elsewhere.

The surveys examined not only the power frequency (60 Hz) electric and magnetic fields associated with Canadian housing but also their harmonic content, transients, attenuation, net current, multi-ground system problems, "hot spots" and mitigation procedures.

Other bands of the electromagnetic spectrum were probed: DC (or static, non-varying) magnetic fields, radiofrequency and microwave and the ELF (extremely low frequency, 1-1000 Hz). Since the beginning of this project in 1993, these other EMF bands have caught the interest of authoritative EMF researchers worldwide trying to understand EMF in housing.

The results to date indicate a great variety of situations – essentially each dwelling presents its own special EMF case. There does not exist one EMF formula for all Canadian housing. Yet enough is now understood about EMF dynamics that it is already possible to begin providing useful corrective educational initiatives to the CMHC audience. Enough experience has been acquired from the survey that it is possible to provide know-how on many EMF mitigation procedures which are not only simple, inexpensive but also very effective.

Worldwide developments in ELF standards and regulations have been accelerating rapidly towards the lower thresholds, lower than many of the magnetic and electric field levels that have been documented during the surveys. This international trend so be impacting on CMHC's range of operations and contacts and it is good that the corporation is now in a position of being informed and "on top of the rising tide." The "CMHC houses" came out as among the "best" and the lowest EMF cases surveyed so these corporation initiatives may be levered as examples to follow.

Nevertheless, there still is more work to be done on the basis of the acquired expertise and momentum, probably in conjunction and co-operation with other agencies across Canada and perhaps the United States which can further cost-effective, efficacious remedial EMF action in Canadian housing in short order.

These are described in the recommendations. They could be annexed as an extension to the existing project.

During the pursuit of this survey, bridges were built with other authoritative parties across Canada and enough interest has come this way on which it might be possible to negotiate joint action, probably along the example of the inter-agency, inter-governmental and enterprise partnership EMF RAPID process undertaken south of the border and other initiatives in the European Union.

The EMF situation in Canadian housing is more acute than elsewhere because of the harsher climate, transmission and distribution technology, the higher electricity-associated consumer lifestyle. This fact alone should serve as an extra stimulus for intelligent policy development now that it is clear that the mitigation involved is actual at nominal cost and involves more careful dissemination of know-how rather than the disbursement of budgetary expenses.

The Corporation should be proud of its initiative in their emerging area, especially in the midst of earlier resistance and commotion.

SURVEY HIGHLIGHTS

36 dwellings, 43 surveys, 338 rooms.

Average **EMF occupant exposure** in Canadian dwellings ranges from between **1.49** milliGauss (mG) in room centres during low-appliance-use conditions to **5.44** mG, in rooms corners, during high-appliance-use.

Highest room centre EMF levels were recorded in kitchens and dining rooms

Bedrooms corners have the **highest fields in any lived-in zone (6.06** mG master bedroom, **7.45** mG for childrens' bedrooms). This is associated with the prevalence of "hot spots" from appliances, and for children with smaller space in the rooms.

Community density is a major factor in EMF levels. Living in the urban core may mean being exposed to fields about double those in low density neighbourhoods.

Brick buildings tend to have the highest EMF (average room centre value: 2.56 mG compared to the lowest, wood structure at 0.84mG). This may be associated with the older buildings and electrical code norms, wear and tear, re-wiring, knob-and-tube wiring, etc...

There is almost a slight advantage in having underground electrical distribution system.

Age of structure is a very significant determinant for EMF levels. Housing built since the 1971 has about half the EMF levels as before.

Single housing units have almost half the EMF of multiple units.

The average sized homes have by far the highest EMF, 3x higher than large homes.

EMF levels are not related to **power consumption** (unless they are designed for energy conservation and energy efficiency).

Net current, is a major source of EMF's in many Canadian dwellings. It is a characteristic of the existing electrical transmission and distribution technology but the problem can be easily mitigated or designed-over, as demonstrated in the study. When present, net current results in average room centre fields of **2.84** mG and **7.89** Mg in room corners.

When **outdoor EMF** are elevated (over 2 mG), they are the predominant cause of indoor EMFs characteristics.

Electric fields in Canadian housing are higher than expected and may become higher still with the emergence of smart controls and switches.

EMF transients can be very remarkable and surging up to 10x average current levels, especially during hours of greater dwelling occupancy. Unpredictable **harmonics and secondary frequencies** can be occur in dwellings due to little understood EMF artefacts.

The **"CMHC houses"** had very low fields: **0.56** mG at room centres and **2.30** mG at corners. (They are located in all community density contexts).

Some **appliances**, such as microwave ovens, and some **personal devices** (fans, vacuums cleaners, shavers, etc.) produce very high power-frequency magnetic fields and the public does not seem to be aware enough to undertake prudent avoidance.

There are no important **radio frequency and microwave** power densities surveyed. Though this is an emerging and widespread technology it is still not affecting Canadian housing at large.

Soil resistivity, especially in the variable Canadian climate, affects indoor EMFs in special ways when there is net current and this situation merits understanding and mitigation.

Almost half of the bedsites surveyed had some **DC (static) magnetic field disturbance** due to the presence of dense metallic objects located a story below – bedrooms above garages, kitchens – but only 1 case in 10 was significant.

6 EMF mitigation exercises were conducted – demonstrating that it is possible to develop simple, cost-efficient and efficacious EMF reduction but the techniques are little known by those who should ultimately apply these.

The current **Canadian Electrical Code** is "solid" and should be more closely applied to resolve housing-related EMF problems.

Enquête sur l'intensité des champs électromagnétiques dans les habitations canadiennes

RÉSUMÉ

Cette enquête a été réalisée à partir d'un échantillon représentatif réduit mais riche d'habitations de l'ensemble du Canada. Le protocole détaillé appliqué se prête à l'élaboration de renseignements utiles. Il est aussi compatible avec des exercices comparables réalisés ou prévus ailleurs.

Dans le cadre de l'enquête, on a étudié non seulement l'intensité des champs électriques et magnétiques à la fréquence industrielle (60 Hz) associée aux habitations canadiennes, mais aussi leur composante harmonique, leurs transitoires, leur atténuation, leur courant net, les problèmes des installations à mise à la terre multiple, les « points chauds » et les procédures d'atténuation.

D'autres bandes du spectre électromagnétique ont été sondées : les champs magnétiques du courant continu (CC) (ou statique, non variable), les radiofréquences, les micro-ondes et la fréquence extrêmement basse (FEB, 1 à 1000 Hz). Depuis le début de cette initiative en 1993, ces autres bandes de champs électromagnétiques (CEM) ont attiré l'attention de chercheurs mondiaux faisant autorité en matière de CEM qui tentent de comprendre les CEM dans l'habitation.

À ce jour, les résultats indiquent une grande diversité de situations, mais essentiellement, chaque logement présente son propre cas spécial de CEM. Il n'existe pas de formule de CEM unique pour l'ensemble des habitations au Canada. Nous en connaissons toutefois suffisamment aujourd'hui à propos de la dynamique des CEM pour qu'il soit possible de lancer des initiatives visant à fournir, à l'auditoire de la SCHL, des informations utiles sur les mesures correctives à prendre. L'expérience acquise grâce à l'enquête est suffisante pour qu'on puisse transmettre des connaissances sur de nombreuses procédures d'atténuation des CEM qui sont non seulement simples et peu coûteuses, mais également très efficaces.

À l'échelle mondiale, les progrès accomplis au chapitre des normes et règlements visant les FEB se sont accélérés rapidement pour en arriver à des seuils plus bas, moins élevés en fait que bon nombre des niveaux de champs magnétiques et électriques relevés lors de l'enquête. Cette tendance internationale aura une incidence sur l'ensemble des activités et des relations de la SCHL, et c'est une bonne chose que la Société soit maintenant en position d'être informée et qu'elle se situe « en haut de cette nouvelle vague ». Parmi les

cas étudiés dans le cadre de l'enquête, les « maisons de la SCHL » se sont classées parmi les « meilleures » et les cas de CEM les plus faibles; on peut donc conclure que les initiatives de la Société peuvent être citées comme étant des exemples à suivre.

Néanmoins, il reste beaucoup de travail à faire pour profiter de l'expertise et de la vitesse de croisière acquises, probablement avec la collaboration d'autres organismes du Canada et peut-être des États-Unis, ce qui permettrait rapidement de rendre plus rentables et efficaces les mesures correctives visant les CEM dans les logements canadiens. Ces mesures sont décrites dans les recommandations. Elles pourraient être annexées à l'initiative existante.

Au cours de la réalisation de cette enquête, des ponts ont été établis avec d'autres intervenants sérieux provenant de tous les coins du Canada. L'intérêt ainsi soulevé donne à penser qu'il serait possible de négocier une intervention concertée, probablement à l'image du processus de création d'un partenariat réunissant organismes, gouvernements et entreprises amorcé au sud de la frontière (EMF RAPID) ainsi qu'à d'autres initiatives de l'Union européenne.

La situation des CEM dans les logements canadiens est plus préoccupante que partout ailleurs en raison du climat plus rigoureux, de la technologie de transmission et de distribution et du mode de vie des consommateurs davantage associé à l'électricité. Ce fait devrait à lui seul servir de stimulus supplémentaire à l'élaboration de politiques intelligentes, maintenant qu'il est clair que les mesures d'atténuation sont réalisables à peu de frais et qu'elles exigent que la diffusion du savoir-faire soit mieux planifiée plutôt que d'avoir à prévoir des dépenses budgétaires.

La Société devrait être fière de l'initiative qu'elle a prise dans ce nouveau domaine, particulièrement dans un contexte marqué par la résistance et la confusion.

POINTS SAILLANTS DE L'ENQUÊTE

36 logements, 43 questionnaires, 338 chambres.

L'**exposition** moyenne **aux CEM des occupants** de logements canadiens varie de **1,49** milligauss (mG) au centre des pièces pendant une faible utilisation des appareils à **5,44** mG dans le coin des pièces pendant une forte utilisation des appareils.

Les **CEM plus élevés au centre des pièces** ont été enregistrés dans les cuisines et les salles à manger.

Les **CEM les plus élevés de n'importe quelle aire habitable** ont été enregistrés dans les chambres **(6,06** mG dans les coins des chambres principales, **7,45** mG dans les chambres d'enfants). Cette situation est due à la prévalence des « points chauds » provenant des appareils et aux dimensions plus petites des chambres d'enfants.

La **densité d'occupation du quartier** constitue un facteur important dans l'intensité des CEM. L'exposition aux champs dans un centre-ville peut atteindre le double de celle enregistrée dans un quartier de faible densité.

Les CEM dans les **immeubles de brique** ont tendance à être plus intenses (valeur moyenne au centre d'une pièce : 2,56 mG comparativement à 0,84 mG, la plus faible intensité pour une structure en bois). Une construction réalisée selon les exigences d'anciens codes du bâtiment et d'électricité plus anciens, l'usure normale, l'installation de nouveau câblage, la filerie bouton et tube, etc., peuvent expliquer ce résultat.

Le système de distribution d'électricité souterrain peut présenter de légers avantages.

L'âge de la structure est un facteur déterminant de l'intensité des CEM. Les habitations construites depuis 1971 ont des CEM de moitié inférieurs à ceux des maisons précédentes.

L'intensité des CEM dans les **maisons individuelles** est environ deux fois moins importante que celle des collectifs d'habitation.

Les maisons de taille moyenne ont de loin les CEM les plus élevés, soit trois fois plus intenses que dans les grandes maisons.

Les CEM ne sont pas liés à la **consommation d'électricité** (à moins que les logements ne soient conçus pour être éconergétiques).

Le courant net est une source importante de CEM dans de nombreux logements canadiens. Il s'agit d'une caractéristique de la technologie actuelle de transmission et de distribution de l'électricité, mais le problème peut être facilement atténué ou contourné, tel que le démontre l'étude. Lorsqu'il est présent, le courant net produit des champs moyens de **2,84** mG au centre des pièces et de **7,89** mG dans le coin des pièces.

Lorsque les **CEM extérieurs** sont élevés (supérieurs à 2 mG), ils sont la principale cause des caractéristiques des CEM à l'intérieur.

Les **champs électriques** dans les logements canadiens sont plus élevés que prévu et pourraient même s'intensifier avec la venue de nouveaux contrôles et commutateurs intelligents.

Les **transitoires de CEM** peuvent être très remarquables et provoquer des surtensions pouvant atteindre 10 fois les niveaux d'intensité moyens, particulièrement pendant les heures où les logements sont les plus occupés. Des **harmoniques et des fréquences secondaires** imprévisibles peuvent se produire dans les logements en raison d'artéfacts de CEM peu compris.

Les « **maisons de la SCHL** » avaient des champs très faibles : **0,56** mG au centre des pièces et **2,30** mG dans les coins. (Elles sont situées dans des collectivités présentant diverses densités).

Certains **appareils**, tels que les fours à micro-ondes, et certains **accessoires personnels** (ventilateurs, aspirateurs, rasoirs, etc.) produisent des champs magnétiques à très haute fréquence et le public ne semble pas être suffisamment conscient du danger pour éviter de les utiliser.

Aucune densité de puissance importante **émise par les fréquences radio et les micro-ondes** n'a été relevée pendant l'enquête. Même s'il s'agit d'une technologie nouvelle et répandue, elle n'a toujours aucune incidence sur les logements canadiens dans leur ensemble.

La **résistivité du sol**, particulièrement dans les conditions climatiques variables du Canada, a des répercussions spéciales sur les CEM intérieurs en présence d'un courant net, et cette situation mérite qu'on s'y attarde afin de la comprendre et de pouvoir l'atténuer.

Près de la moitié des chambres étudiées comportaient une **déviation du champ magnétique du CC (statique)** en raison de la présence d'objets métalliques denses situés à l'étage au-dessous, comme c'est le cas des chambres aménagées au-dessus d'un garage ou de la cuisine, mais seulement un cas sur 10 présentait une déviation importante.

Six exercices d'atténuation des CEM ont été effectués afin de démontrer qu'il est possible d'en arriver à des mesures d'atténuation des CEM simples, peu coûteuses et efficaces; cependant, ces techniques sont peu connues par les personnes qui devraient, en bout de ligne, les appliquer.

Le ***Code canadien de l'électricité*** est « solide » et devrait être observé plus rigoureusement afin de régler les problèmes de CEM en milieu résidentiel.

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SURVEY OF ELECTROMAGNETIC FIELD LEVELS IN CANADIAN HOUSING

1. INTRODUCTION

The *problematique* of electromagnetic fields (EMF) and especially in the extremely low frequency range (0 to 1,000 Hz) range has been the subject of extensive interdisciplinary research. A recent government EMF status report survey lists numerous studies: epidemiological, animal tumor, reproductive and developmental, immune system, physiological, and neurological and behavioural studies, as well as cell-level research and efforts at electromagnetic field reduction and mitigation.

Evidence has been mounting regarding the adverse effects that EMF can pose. An important early research publishing the results of a study of childhood deaths from cancer in Denver, Colorado was conducted by Dr. **Nancy Wertheimer** and Prof. **Ed Leeper** in 1979. They showed that children had double to triple the chance of developing leukemia, lymphoma or tumors of the nervous system if they lived near high-current wiring and its associated EMF than if they did not. Several other studies followed in the 1980's and the one taken most seriously was published in 1988 by Dr. **David Savitz** who repeated the Wertheimer and Leeper study with better epidemio-logical methodology and got similar results. A 1992 Swedish study by **Maria Feychting** and **Anders Ahibohm** of the **Karolinska Institutet** which considered the entire Swedish population showed triple the risk of contracting leukemia in children who lived in houses with fields of at least 2 milliGauss (mG) compared with those living among fields down to 1 mG. The 1993 Danish study led by **J. H. Ohlsen** noted a significant association between the sumtotal of all major types of childhood cancer and exposure to fields higher than 4 mG.

However, as the study designs are improving, the EMF exposure risk ratios continue to remain the same – between 1.5 to 3 – an anomaly in itself. **Gilles Thériault of McGill University** suggests that perhaps some other aspect of EMF exposure may play a key role other than the intensity of fields: such as the nature (intensity and frequency) of transients phenomena associated with electrical transmission systems. Others suggest the importance of night-time exposures or the combinatory effect of static magnetic field levels coupled with the 50 or 60 Hz fields. Nevertheless, the near-2 ratio, for a pheno-menon of such massive prevalence, still constitutes a major "societal factor" in the view of public policy experts at **Carnegie Mellon University**.

All this research into various aspects of EMF has engaged considerable funding. By mid-1994, there were documented nearly 350 research projects worldwide – 280 EMF biological, 80 engineering and 1 risk perception studies were either ongoing, planned or completed. Of these studies, less than a third were completed, costing altogether an estimated $ 55 million. In the United States, pursuant to the 1992 ***Energy Policy Act***, the 5 year ***EMF RAPID*** (Research and Public Information Dissemination) program was established. Designed to ensure that remedial action taken by the Government on electric and magnetic fields would be based on, and consistent with, scientifically valid research, the program was budgeted almost $ 90 million over 5 years. Some of its funding was committed by the electric utility industry and the electrical manufacturers, who together committed almost $ 33 million. Aside risk determination and mitigation technology development thrusts, RAPID is to disseminate information on such matters as:

a) types and extent of human exposure to EMF in various

occupational and residential settings;

b) technologies to measure and characterize EMFs;

and, finally:

c) methods to assess and manage exposure to EMFs.

EPRI (Electrical Power Research Institute) has spent over $ 100 million to date and plans to spend another $ 70 million by the fiscal year 2,000 on EMF research.

The emphasis among the utilities and researchers so far seems to be "prudent avoidance" -- or, more-or-less, increasing distance from a source of high fields or reducing time spent in high fields. But it is being also noted, with the increasing availability of survey data that, in most cases, mistakes in building wiring -- incorrect grounding, shunting of the neutral current and poor work by electricians are the main cause of excessive magnetic fields. Also, greater interest is being devoted to modifying conductor spacing and phase arrangement in both overhead and underground electrical transmission systems in order to maximize magnetic field cancellation -- an initiative which simply requires low/no cost changing the conductor bus connections at substations.

An important trend has been rapidly emerging with regards to extremely low frequency EMF standards development. It involves a decidedly lower threshold of acceptable field levels. In 1993, the **International Commission on Non-Ionizing Radiation Protection (ICNIRP)** -- formed by the **International Radiation Protection Association (IRPA)** determined that the 24 hour general public exposure to 50/60 Hz EMF should not exceed 1,000 mG / 5,000 V/m; and, per "a few hours a day" to 10,000 mG / 10,000 V/m. Workers could receive dosages of up to 250,000 mG. The rationale basis for these standards was that, "exposure to 50/60 Hz should not exceed those which occur naturally."

In 1994, the **European Parliament** resolution "on combatting the harmful effects of non-ionizing radiation" (A.3 - 0238/94) called for the application of the 1990 Swedish MPR II standard for electronic equipment of 2.5 mG and 25 V/m at 50 cm from electronic equipment to be included in the Council Directive 90/270/EEC on the minimum safety and health requirements. The Swedish standard released by **SWEDAC**, the government agency for testing, calibration and measurement was followed by a correction by the **New York State Education Department** which has set a standard in 1992 of 2 mG and 10 V/m at 30 cm. in line with a 1991 **TCO (Swedish Confederation of Professional Employees)** recommendation. ("Low emission" video display terminals are now available from **IBM** with E.L.F. emissions of 0.40 to 0.60 mG at 50 cm.).

On June 13, 1995, the United States **National Council on Radiation Protection and Measurements (NCRP) Scientific Committee 89-3 on Extremely Low Frequency Electric and Magnetic Fields** after 9 years of deliberation, concluded and recommended, in a draft pending peer review, that a 2 mG and 10 V/m exposure guideline be applicable for all new federal projects such as schools, kindergartens, housing and industrial plants. An initial and interim benchmark of 10 mG and 100 V/m would be applicable for existing environmental electromagnetic environments, followed by a review in six years for a guideline of 5 mG and 50 V/m and finally by the application of the 2 mG / 10 V/m standard. The NCRP committee foresees, "specifications of acceptable intérior electromagnetic environments, as well as proximity to existing electric power transmission and distribution systems."

Over the recent years, the standards have essentially dropped from as high as 250,000 mG (for the occupational exposure) or 1,000 mG (for the general population rexposure) to 2 mG, from 30,000 V/m - 5,000 V/m respectively to only 10 V/m.

The **Canada Mortgage and Housing Corporation**, through its ***Healthy Housing*** initiative has been spearheading the Canadian thrust for coping with the eventual coming to terms with this international EMF development as it interfaces with Canadian housing, and this survey is an example in question. The forward-looking posture of certain officials, including **Christopher Ives**, and Dr. **Virginia Salares** was a necessary and integral part in blazing the path to enabling Canadians to live in houses which can meet the lowest possible electromagnetic fields levels with minimum effort and cost.

The considerations and support of other Canadian institutions in the process of this survey and its development are also appreciated. They include (in alphabetical order): **BC Hydro, Bell Mobility, British Columbia Department of Health, Canadian Home Builders Association, Edmonton Power, Environment Canada, Federation of Canadian Municipalities, Manitoba Hydro, National Research Council, Natural Resources Canada and Ontario Hydro.**

The constructive reviews and contributions by Prof. **Paul Héroux of McGill University** and Dr. **Doreen Hill of Energetics** were instrumental to the final outcome of this study.

2. THE STUDY TEAM AND THE INTERDISCIPLINARY RESOURCE NETWORK

2.1 Principal Study Team Members

Dr. A. **Michrowski** (D. Arch, **Politecnico di Milano**), Architect, is an expert in electromagnetic issues concerning the built environment. He has conducted hundreds of EMF surveys in residences and office premises since 1979. He has successfully designed and supervised sensitive evaluation research analyses with the Canadian government, as Senior Policy Analyst at **Secretary of State** and as Chief Planner of **Indian and Northern Affairs Canada**. He has edited critical, annotated reviews of the world literature on electromagnetic bioeffects, and has published such monographs as ***The ELF factor***, ***Studying problems associated with video display systems***, ***Harmonizing indoor EMFs***. Has addressed before professional engineering, scientific, medical and government bodies on the subject and has given EMF mitigation workshops since 1991. He is President of the **Planetary Association for Clean Energy**, Inc., a Canadian Learned Society which is recognized by the **United Nations**.

He headed the project team, leading both the state of the art review as well as the field surveys and provided liaison with the CMHC Research Division.

Prof. **Monique Michaud** (M.Sc. Architecture, **Université de Montréal**; C.G.D [Law], **University of Ottawa**) Works in the domain of environmental design/human ecology concerns. She has extensive experience in electromagnetic surveys in housing. Formerly Professor of environmental design at **UQAM (Université du Québec à Montréal)**, and long-term consultant to government agencies on complex projects, often including comprehensive questionnaires: **Bureau of Management Consulting** with **Supply and Services Canada, Public Works Canada** as well as to major Canadian and Italian architectural firms: **Raymond Moriyama, Daniel Lazosky, David, Barrott, Boulva** and **A. Mangiarotti.** She is President of **Essentia Communication,** Inc., a company dealing with environmental EMF scientific equipment and services.

She brought her experience in questionnaires, checklists and like field work to ensure the quality and consistency concerns related to the choice of houses, the data collected in the field surveys, the breadth and scope of the interim and final reports, soliciting and coordinating the reviews and comments of the project team members.

Meludin Veledar (B.Sc and M.Sc. in Electrical Engineering, **University of Sarajevo**), was formerly with **Energoinvest - Power Institute** where he was a member of the Board of Directors and managed the 25 employee High Voltage Laboratory (with four labs ranging from 35 - 500 kV). He developed expertise in advanced grounding techniques. He taught high voltage technology (including equipment testing) at the University of Sarajevo and participated in the formation of the Bosnia and Herzegovina national CIGRE and was member of the former Yugoslav CIGRE Study C*ommittee 22 (Overhead Lines)*. He has over 25 publications. He has conducted several institutional and housing surveys involving EMI and grounding problems, leading to successful mitigation. He is staff member of the Planetary Association for Clean Energy, where he is preparing an overview of EMF mitigation protocols destined for the building trades.

He brought his experience to ensure technical consistency in the field surveys and maximum effectiveness and cost-efficiency in the mitigation activities applied.

Dr. **Jerzy Kulczycki** (Ph.D. [Biochemistry], **Polish Academy of Sciences**; M.Sc. [Biology], **University of Lodz**), Environmental toxicologist, formerly with a Hygiene Research Station in Poland where he headed biochemical and radiation contamination sections (3 laboratories). Author of ***Basis of electromagnetic hygiene*** and numerous scientific papers. Extensive experience in electromagnetic surveys and in designing engineering solutions alleviating electromagnetic problems in houses. A staff member of the Planetary Association for Clean Energy, he is currently on contract with **Carleton University** diagnosing biological specimens for organism effects resulting from EMF.

He brought his experience to ensure technical and scientific consistency and rigour in the literature search (ensuring direct access to Eastern sources) as well as in the field surveys (and their checklist of concerns) and in their protocol and in the subsequent determination of remedial action.

Prof. **Lynn Trainor** (Theoretical Physics, **University of Minnesota**), Biophysicist with special focus on the electromagnetic interactions with living systems, currently at the Department of Physics, **University of Toronto.** He has particular interest in the environmentally sensitive. Advises Dr. **Rosalie Bertell's International Institute for Concern of Public Health** on electromagnetic radiation matters.

He brought his considerable academic and theoretical experience to the various key phases involving the proper information recording procedures for each survey (and accompanying questionnaire, its compilation for analysis and, finally, a critical review of the reports to the CMHC Research Division.

Chris Anderson (B.A., **Carleton University**), Independent building tradesman with over 20 years' experience in home electronics and electrical renovation work. After training from the Planetary Association for Clean Energy, Inc, has been conducting electromagnetic field surveys in residences throughout British Columbia.
He assured support during field surveys in British Columbia, allowing access to characteristic survey choices, and contributed to remedial considerations.

Support at the secretariat level during the 3 years for the project was provided by: **Pierre Dallaire,** B.Sc, (University of Ottawa) (state-of-the-art review development), **Eric A. Michrowski**, (University of Ottawa) (with the computer software and data processing and analysis), **Lan Jin** M.Eng. and **Prof. Pelayo Calante Garcia**, M.Eng. (surveys, data logging and compilation) and **Ludmila Ten** (state-of-the-art-review development)

2. 2 Outside consultation

Outside consultation was contracted for the initial, interim and final stages of the Study, including the 1) survey preparatory, 2; qualitative analysis of the data developed from the field surveys and questionnaires; and, 3) the summary of outline scenarios to the building practice and remedial measures in high exposure residential situations. The source of these consultants is in the architectural and building community. The key individuals whose services were drawn upon as needed were (in alphabetical order) :

Richard L. Crowther, FAIA, Architect known internationally as a pioneer in passive energy efficient systems and in the concern for the practical resolution of electro-magnetic problems in housing. He is author of the comprehensive outlined study, ***Ecologic Architecture*** as well an extensive list of books and publications.

Oliver Drerup, specialist in building innovative healthy and energy efficient houses. He is principal of **Drerup Armstrong Construction Limited**.

Ian Le Cheminant, contractor (**Building Technology Research & Services**) in building ecology with experience in the practical application of non-toxic methods of construction, located in British Columbia.

Mario Kani, P.Eng, building designer and researcher (**Allen Associates**) specialised in environmentally appropriate housing with considerable advanced mechanical skills.

Ed Lowans, specialist in research and design of housing-related concerns and remedies for the environmentally sensitive. He was President of the **Allergy and Environmental Health Association of Canada**.

THE ELECTROMAGNETIC FREQUENCY SPECTRUM

Electromagnetism is classified into two sections: ionizing and non-ionizing radiation. Non-ionizing radiation consists of electromagnetic waves below the visible spectrum, with frequencies ranging from near zero to 10^{17} Hertz (Hz) and with quantum energy levels of less than 12 eV (electron volts) which is not enough to ionizing (or stripping electrons from atoms or living molecules through which they pass). Ionizing radiation, comma, on the other hand, is that radiation whose frequency range goes from 10^{18} to 10^{22} Hertz and whose quantum energy is higher than 12 eV.

Non-ionizing electromagnetic radiation is divided into seven groups as shown on the following table.

Extremely low frequency	ELF	0 - 1,000 Hz *
Very low frequency	VLF	1 - 200 kHz
Radio frequency	RF	0.2 - 300 MHz
Microwave	mw	0.3 - 300 GHz
Infrared	IR	300 - 400,000 GHz
Visible		400,000 - 800,000 GHz
Ultraviolet	UV	800,000 GHz - X-rays **

* according to generally accepted usage in Europe, the band from 30 to 300 Hz is designated as Extremely low frequency; the region below this ELF band is unnamed. In the U.S., ELF are sometimes designated as 0 to 100 Hz.

** Ultraviolet (UV) radiation ranges from the shortest visible waves (violet to 400 to 420 nanometres) to the longest roentgen radiation (x-rays) of 3.5 nanometers.

Figure 1

The Extremely Low Frequency (ELF) electromagnetic spectrum

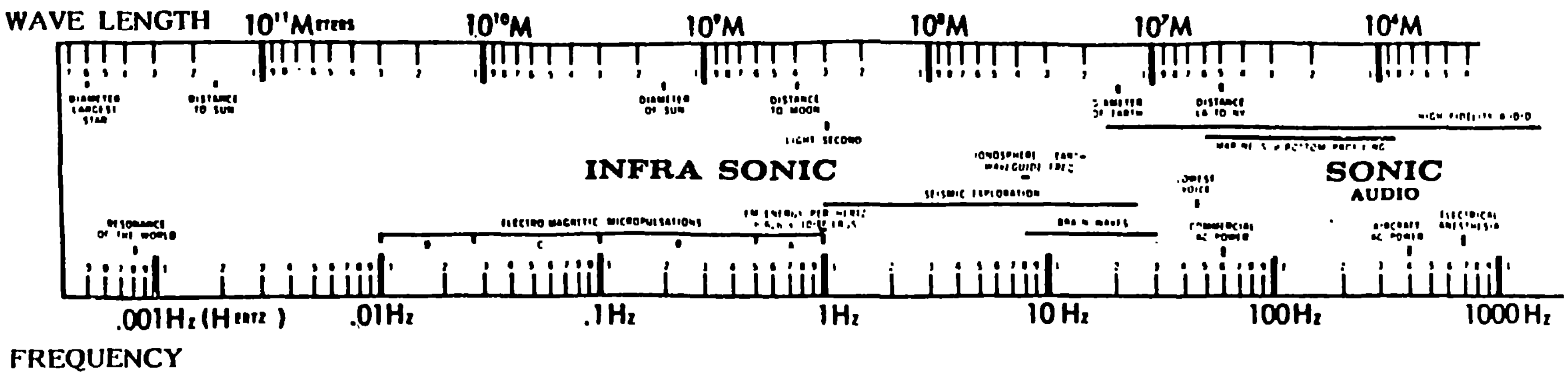


Figure 2

The Very Low Frequency (VLF) electromagnetic spectrum

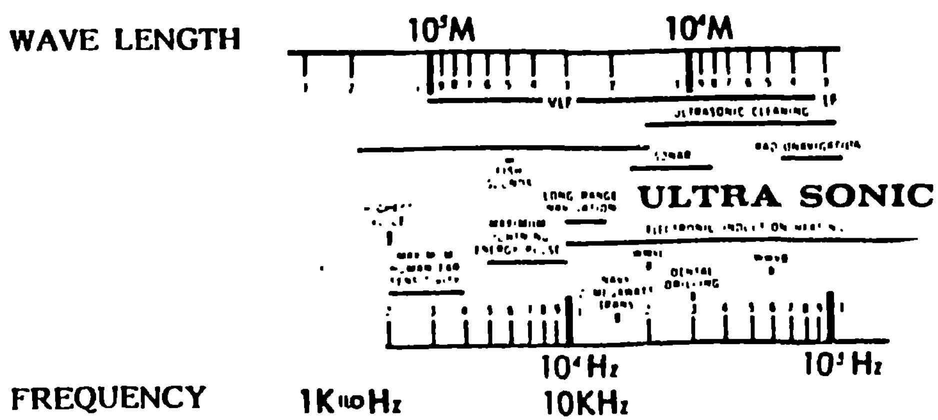


Figure 3

The Radiofrequency (RF) and Microwave electromagnetic spectrum

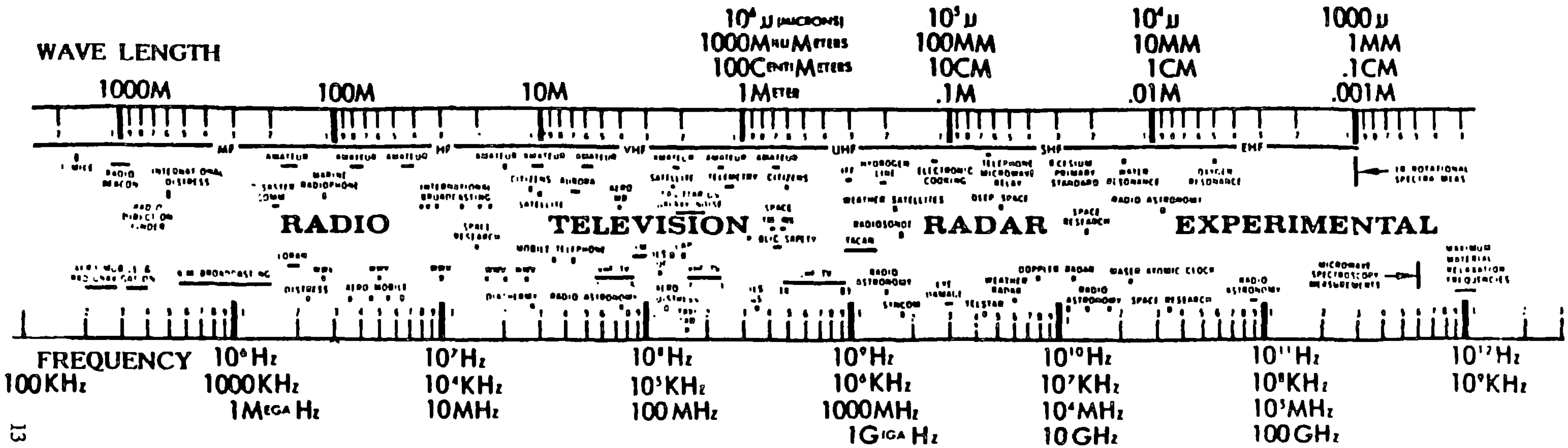
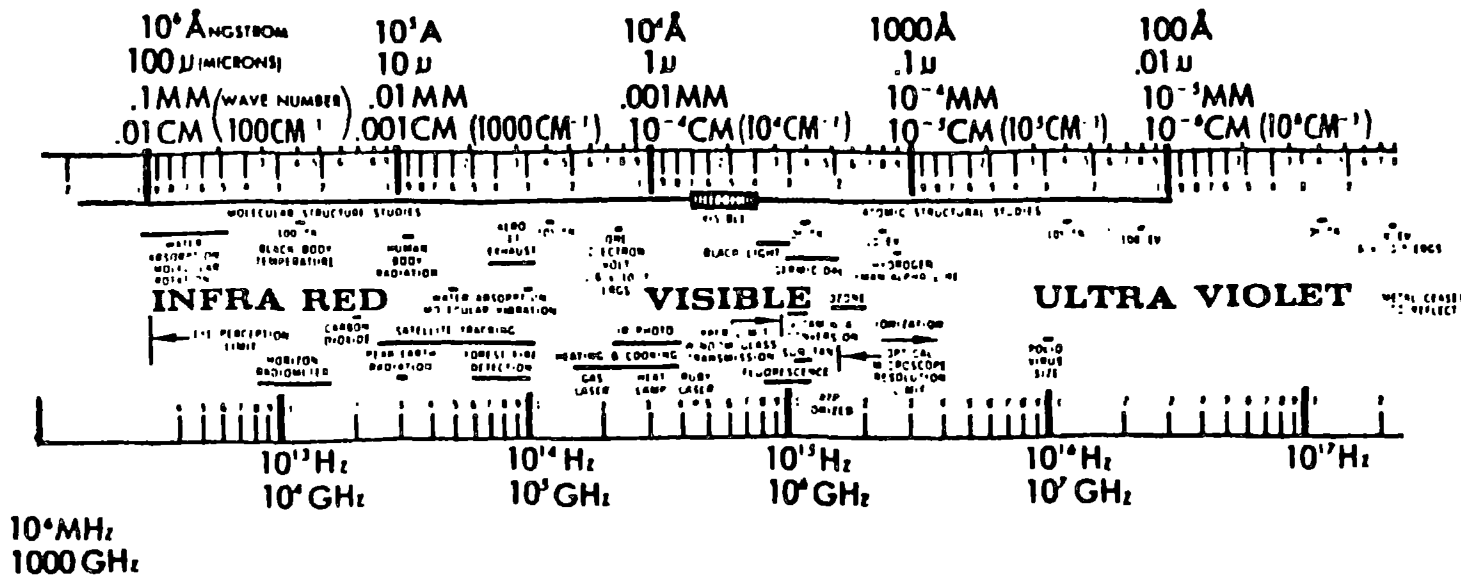


Figure 4

The Infra Red (IR), Visible and Ultra Violet (UV) electromagnetic spectra



3. OVERVIEW OF THE HOUSING-RELATED RESEARCH ON ELECTROMAGNETIC FIELDS

3.1 HOUSING EMF CHARACTERISTICS

Housing related EMF fall into several commonly investigated groupings: 1) transmission and distribution power lines; 2) household wiring and *net currents*; 3) appliances. This study also examines aspects of the static magnetic field and radio-frequency/microwave factors of the housing environment.

An overview of household magnetic fields near power transmission lines and household appliances is adapted from a 1993 **Bonneville Power Administration** study:

EMF source	0.30 m	1.00 m	Right of way	15 m	33 m	66 m
	in milliGauss (mG)					
115 kV line (average load)			30	7	2	0.4
115 kV line (peak load)			63	14	4	1.0
230 kV line (average load)			58	20	7	2.0
230 kV line (peak load)			118	40	15	4.0
500 kV line (peak load)			138		27	7.0
Television	2 - 30	0.1 - 2				
Electric stove	4 - 40	0.1 - 1				
Microwave oven	40-80	3.0 - 8				
Fluorescent lamp	5 - 20	0.1 - 3				
Hair Dryer	1 - 70	0.1 - 3				
Electric Razor	1 - 90	0.4 - 3				

In 1984, **World Health Organization** portrayed the 60 Hz electric field levels at the center of various rooms in a typical U.S. home in this way:

Location	**Volt/metre**
Laundry room	0.8
Dining Room	0.9
Bathroom	1.2 - 1.5
Kitchen	2.6
Bedroom	2.4 - 7.8
Living Room	3.3
Hallway	13.0

The fields from transmission power lines tend to vary slowly over time and produce continuous EMF. Appliances emit stronger, highly user-dependent, fields indoors that are usually short-term and discontinuous. These fields attenuate rapidly as a function of distance. EMF from appliances can vary considerably according to the manufacturer and assembly-line unit so they cannot be easily generalised.

3.1.1 Transmission and distribution power lines

As a source of EMF, transmission lines have several distinguishing characteristics. Due to their height and conductor spacing, the lines produce magnetic fields with much smaller spatial variation at ground level than fields from most other sources. Variations in time are also smaller. The waveform of transmission line fields is almost sinusoidal – hence liable to generate very few harmonics and their associated higher frequency waves (which is a research area of concern for potential bio-effects). The fields from the transmission lines are mainly oriented in the plane perpendicular to the line.

A variety of techniques have been identified by the United States Electrical Power Research Institute (EPRI) to exist to reduce the intensity of transmission and distribution line fields as experienced in housing located near to these:

1) ***compaction of lines*** – bringing the conductors closer together, allows the fields produced by the different conductors to more nearly cancel each other;

2) ***phase-splitting*** carries this technique still further by assigning multiple conductors to each phase, thus providing more opportunities for field cancellation – the best configuration being the triangular "delta" suspension layout (which may even allow greater capacity and considerable reduction in magnetic fields – up to *tenfold* field reduction);

3) ***shielding*** by stringing sections of wire loops parallel to transmission lines. Such loops may be designed to act passively with currents induced by powerline EMFs – or actively, with fields imposed to cancel out the transmitted EMF, depending on the desired level of reduction of EMF.

The major source of magnetic fields from overhead distribution lines is unbalanced currents in the three-phase of the powerline.

Ideally, the sum of currents flowing along conductors towards a load – housing along a road, for example – is zero. This means that there is, in such a case, *no net current* along the line, allowing for maximum magnetic field self-cancellation by all the conductors involved.

When a substantial current returns to a distribution transformer through the ground rather than through the neutral conductor of the line, a net current develops. The magnetic field produced by this net current is not canceled and may become a significant source of EMF in nearby homes. **Ontario Hydro Research (D. L. Mader,** ***et al*****)** reported in 1990 that the major contribution to residential 60 Hz magnetic fields probably results from the grounding or "water-pipe" currents caused by local imbalance. Their 50 residential sites study indicated that the residential fields tend to be higher in the summer, highest on a daily basis between 6 PM and midnight.

Because of varying consumer loads, harmonics from household appliances and the fact that quite often part of the current flows into the earth at grounding points, rather than through the return wire of the distribution system, other methods should be used to lower fields from these lines.

A number of better ways must be developed to balance the electrical load -- such as energy convservation and efficiency procedures -- as well reduction of the flow of current in metallic pipes and through the earth. In some cases, line compaction and other changes in conductor configuration (such as the "armless construction" triangular delta configuration, "multiplex" (triplex or quadruplex) wire twisting and braiding, shield wires running parallel to distribution lines) may be helpful in reducing magnetic fields to acceptable levels -- including reduction of EMI (electromagnetic interference) to computers that can be adversely affected by magnetic fields strength starting at near-10 mG. Another method used is an actively driven cancellation loop, which can be combined with shielding schemes.

Residential low-voltage grounding connections -- the neutral wire to ground contacts in houses are crucial since they protect against shock and fire from fault currents.

However, the presence of multi-grounding contacts inside homes is a serious problem. These contacts usually result from wiring errors and, together with the current-carrying metallic water pipes, provide numerous pathways whereby neutral return current may flow back to the utility's distribution system, instead of using the secondary neutral -- and thereby optimize its magnetic field cancellation potential. Such current/ground wire contacts also exist inside hybrid appliances such as ice-makers, gas stoves with electric clocks, gas furnace, electrical water heaters.

The multi-grounding problem exists in both overhead and underground electrical distribution systems.

In existing distribution systems that contain transformer vaults and cable runs in larger buildings, including apartment buildings, the only shielding that appears to be available is with shielding materials such as *Mu-Metal*, thick (up to 1.2 cm) welded low-carbon steel plates, laminated combinations of aluminum and steel plates and specialized heat-treated high permeability nickel alloys, thick (3 cm) parallel honey-combed galvanized steel laminations and some new polymers such but these are all rather costly or wieldy and, despite on-going research, no real promise appears to exist.

Concerning distribution system mitigation options, most of these are a question of costs versus benefits for a particular field mitigation procedure, which may have to be decided upon on a case-by-case basis.

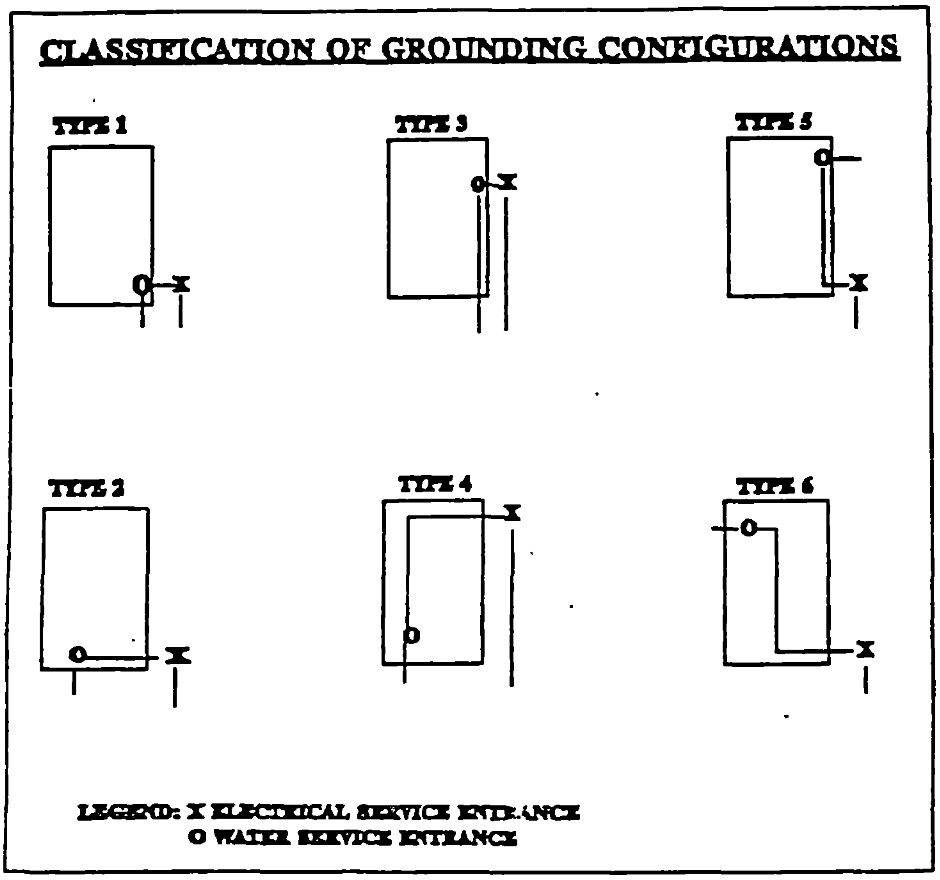
In 1995, EPRI analyzed the various aspects of EMF management as shown below:

Possible Options for Field Management			
Technique	**Effectiveness**	**Cost**	**Issues**
Decrease loop size	marginal to good	moderate to large	feasibility
Increase distance	excellent	small - large	feasibility
Electrical Code compliance	marginal to good	small - moderate	safety
240 V appliances	marginal to good	moderate	feasibility
Load balancing	marginal to good	moderate	feasibility
Improve neutral	marginal to good	small - large	feasibility
Dielectric coupler	excellent	small	safety/code
Neutral Current Coupler/*NCC*	excellent	moderate	safety/code feasibility

A procedure that is being applied throughout Canadian cities is the increase of secondary voltages. Larger consumer bases and increased power consumption have tended to overload the older low-voltage (usually 4,000 Volt) primary distribution systems, which being obsolescent, are being converted to systems operating at voltage typically from 14,000 to 28,000 volts. Increasing the voltage decreases the amperage -- and thus the resulting magnetic field. In this expansion, additional primary and secondary circuits are being added, bringing with them additional substations, transformer stations, additional pole-mounted, pad-mounted or underground distribution transformers, all of which may present new sources of magnetic fields, but many of these are subject to greater mitigation scrutiny at the engineering stages.

The possibility of installing improved neutrals is also an option for the utilities, as noted by EPRI.

Another important mitigation procedure for new homes and for older EMF trouble housing involves the routing of service drops close to residential water pipes, thereby shortening the length of the grounding wire which is liable to carry current -- often near shortening the length of the grounding wire which is liable to carry current – often near lived-in zones in residences. Below are shown a variety of grounding configurations relating the electrical service entrance with the water service entrance.



In recent years, actual mitigation efforts on secondary distribution lines by various utilities in Canada and the United States, the most successful field reductions have occurred mainly by changing to the compacting multiplex cable. These changes are reportedly in part a general, rather than site-specific pressure response to EMF concerns. There have also been cases for relocating particular lines or sections of lines and equipment, for re-configuring secondary leads on transformers and for introducing shielding of some equipment.

Undergrounding is a special form of line compaction, given that buried conductors are usually close together, especially when installed in the delta configuration. However there are underground systems, often found in suburban developments throughout Canada, where other utilities such as water mains, telephone lines, gas mains are combined together – sometimes arbitrarily – and leading to unnecessarily elevated EMF levels.

According to the Canadian experience, the maximum magnetic field "near" a step-down transformer is expected to be in the 1 to 10 mG range and the rate of fall off is very rapid -- as it is for all coiled wire sources – at $1/r^3$. The magnetic field at the pad mounted transformer can be greater than 300 mG, decreasing rapidly to generally below 20 mG at 1 metre.

3.1.2 Household wiring and net currents

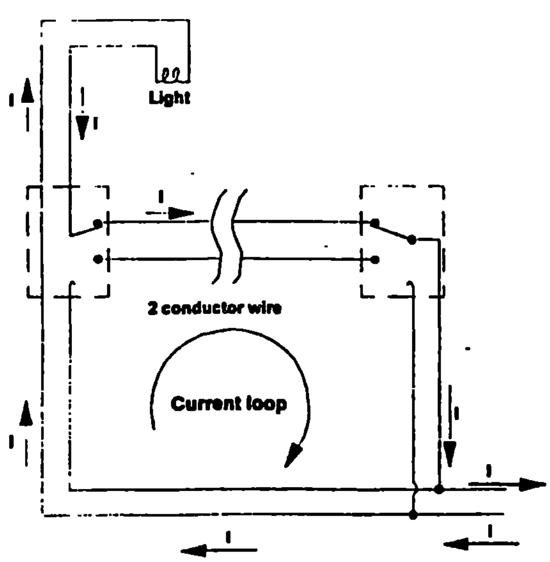
It is the experience of EMF consultants who conduct surveys in residences that about 20% of sources of elevated magnetic fields -- 3 mG and above -- come from powerlines (about 5% transmission, 12 % primary distribution and about 3 % secondary distribution). On the other hand, wiring and grounding problems account for about two-thirds of the high fields. In about 43 %, wiring errors are the identified source of emissions and the water supply pipes are responsible for about 15 %. Appliances account for about 3 % of high fields.

Perhaps only one North American residence out of twenty -- 5 % -- will have no field higher than 1 mG throughout. Clearly wiring errors and currents along water pipes are a major EMF concern in housing.

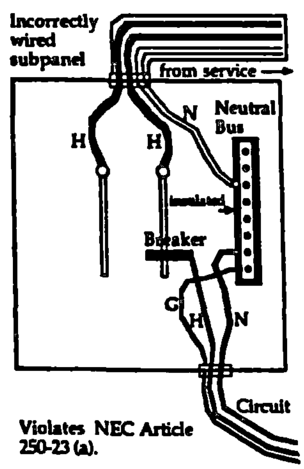
Most of the errors in wiring susceptible to generating high magnetic fields are in fact violations of the ***Canadian Electrical Code***. Such errors will be found in the electrical panel box, in subpanels, junction boxes, receptacles, in multi-locational switching. Other causes of wiring-related high EMF sources are: knob and tube wiring which generally pre-dates the 1950s, 240 V baseboard heaters and inadvertent neutral/grounding wire contacts.

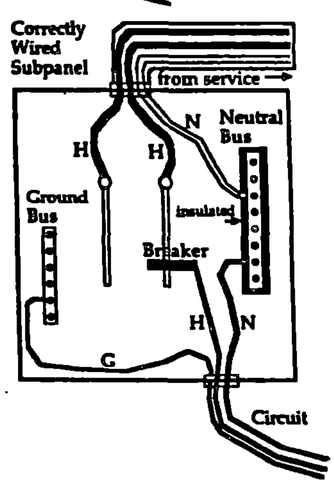
The various problems which results in elevated magetic fields can be explained by way of illustration.

Multi-locational switching (Code violation). The current return wire follows a different path from the supply wire. This configuration induces a *loop circuit* that can cause an entire zone (sometimes several rooms) of a residence gain a very high magnetic field (up to 20X) each time some appliance -- even a small reading lamp -- at the farther end of the circuit is switched *on*. This wiring error is identified when all appliances are turned "*on*".

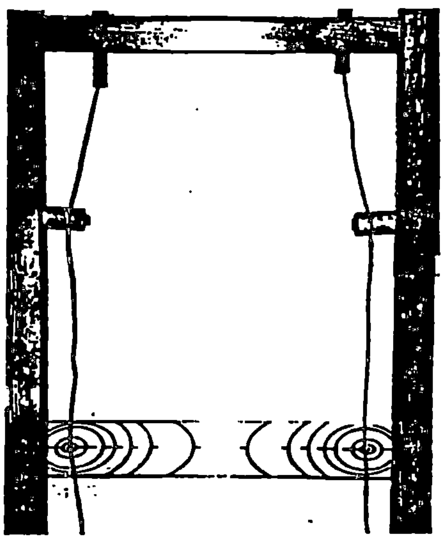


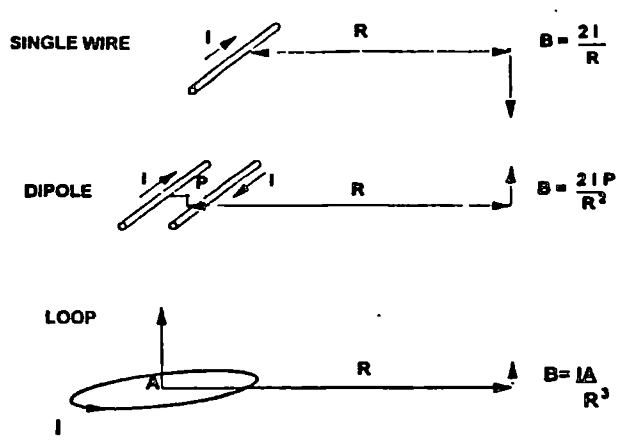
Incorrectly wired sub-panel (Code violation) and a correctly wired one. Equipment grounding must have their own bus. Connection of ground electrode and neutral at subpanel could result in a return path for current that is separated from the current path inducing a *loop current*.



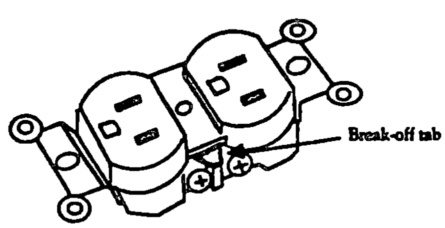


Knob and tube wiring. Wires run individually using porcelain knobs and tubes for insulators. This mode of wiring is still prevalent in the outdoor overhead primary and secondary distribution used by the utilities. The distance between the conductors decreases the ability of field cancellation. The *net current* thus created has a field which drops off at $1/R$ instead of $1/R^2$ or $1/R^3$ (in the case of transformers and most coils).

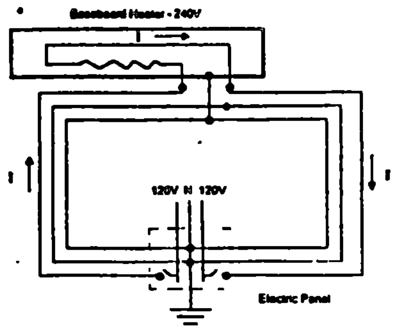




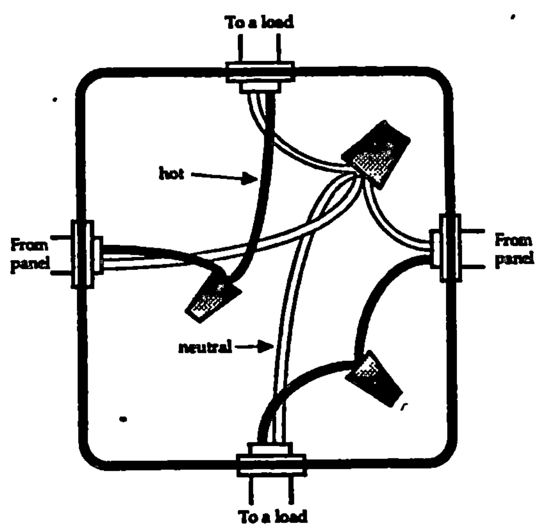
Receptacle with break-off tabs when seperate circuits are feeding each other.



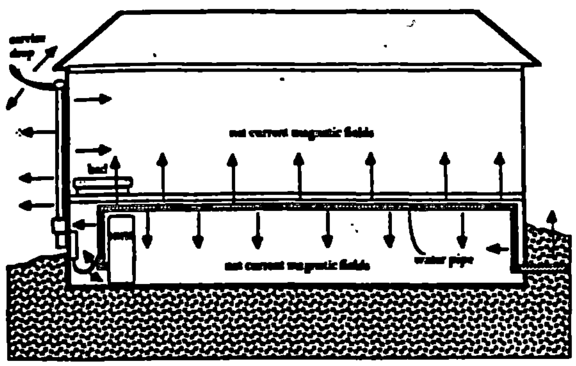
240 volt baseboard heater wired from two separate 120 volt circuits (Code violation). An example of a *current loop*, where the magnetic field effect for 1 Amp at 1 meter = 2 mG.



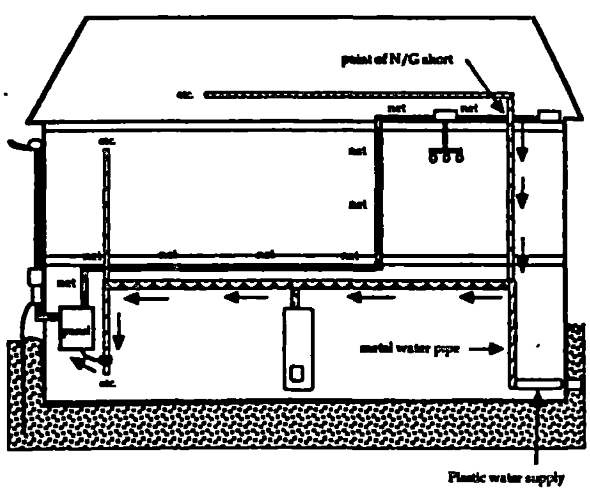
Incorrectly wired junction box (Code violation). Neutrals from two branch circuits are joined, permitting the neutral from either load to run on both circuits in parallel paths in different cables or conduits and generating *loop current*.



Net current -- ***Splitting between service and water system grounding.*** Path of *net current* magnetic fields when neutral return current splits at the service point due to required grounding to a metallic water system which enters at the other end of the house. The water pipe has a current and the service drop has the same net current due to a deficit of the neutral.



Net current -- ***neutral shorting and transfer with other conduits (vents, pipes, etc.)*** In this example, neutral transfers through a contact with a cold water pipe which touches a hot water pipe that transfers current to the grounding conductor back to the panel, producing a *current loop* and high magnetic fields in the entire house. Current path temporarily cut with plastic wedged between vent pipe and cold water pipe.



Elevated EMFs in residential wiring
common sources

"knob and tube" wiring (older locations)
multi-locational switches
corroded groundwire-water main contacts (aging or chemically induced)
improper panel/sub-panel neutral wire installation
physical contact between water, gas and/or air duct conduits and grounding wires
hybrid appliances sharing grounding wires: washers, ice-making refrigerators, gas stoves

3.1.3 Appliances

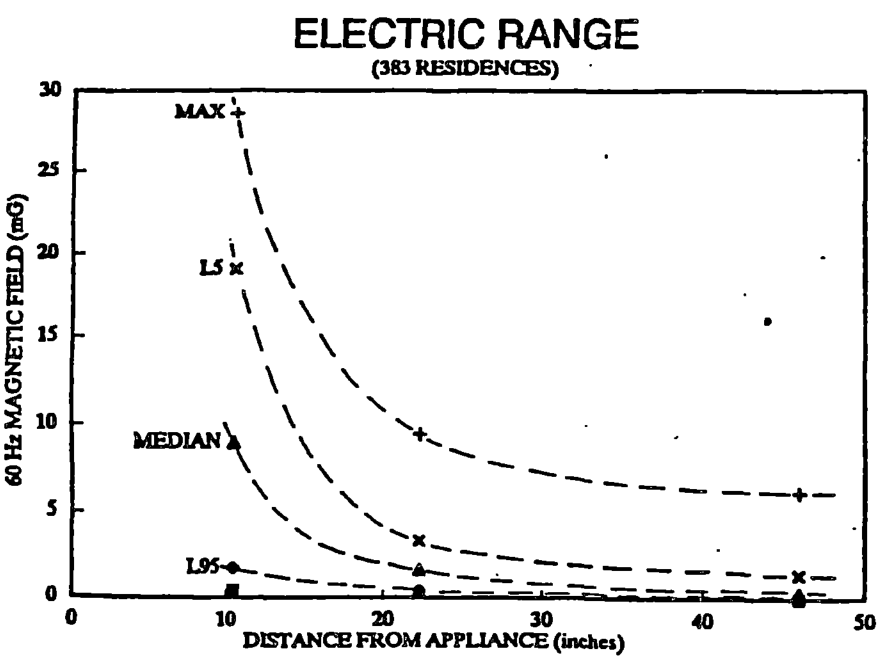
Appliances play a major role in EMF exposure levels inside dwellings. On the other hand, appliances and their use can be more readily be managed by household occupants than power lines or indoor wiring characteristics. Users should be made more aware of the radiation characteristics of appliances and be helped in knowing how to optimize low-EMF deployment and usage -- along the prudent avoidance theme.

Magnetic field levels for some common appliances are described in the household EMF table on page 14. There are aspects of appliance EMF which merit discussion. For example, there is the matter of small, portable and sometimes personal devices -- hair dryers, electric shavers, fans, can openers, mixers, vacuum cleaners, etc. In general, these can produce elevated fields at close range to users and with acute field fluctuations (dB/dt). A 1995 **Battelle Pacific Northwest Laboratory** study shows that electric shavers models may produce anywhere from 20 mG to 5,000 mG, at peak dB/dt from 20,000 Gauss/second to 54,000,000 G/sec. Older small appliances operating directly from 110 VAC with a power cord produce the highest magnetic fields and the highest time-rate-of-change.

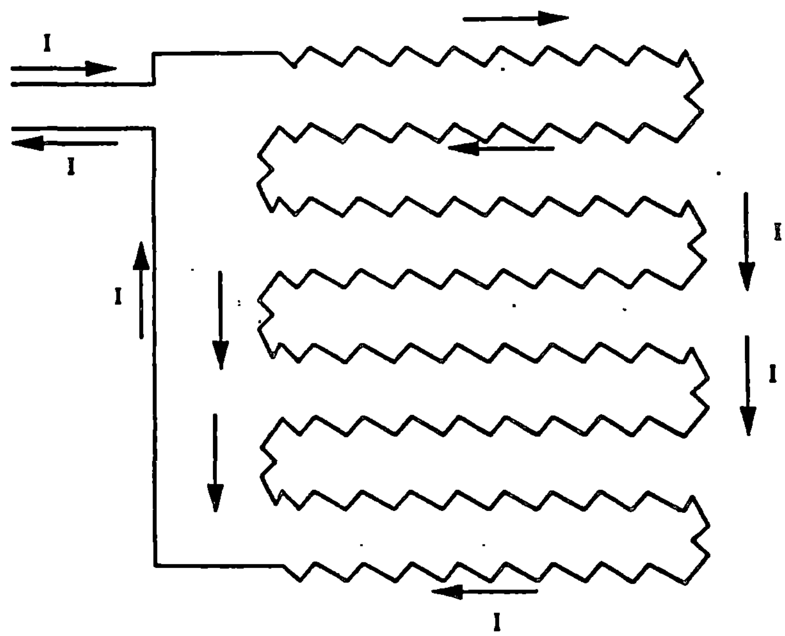
A 3-minute shave with an older razor may easily result in a 1,000 mG exposure to the head that results in a 24-hour weighted average exposure of 50 mG/hour compared with a 48 mG/hr from a 24 hour stay in a home with a 2 mG average magnetic field.

Microwave ovens also produce elevated 60 Hz magnetic fields. Their near fields range from 100 to 300 mG, and at 1.25 meters have intensities in the range of 2 to 20 mG when "*on*" and 1 to 10 mG when "*off*". All this is much higher than electric ovens and electric ranges which are about 5 to 20 X less intense and produce no field when turned "*off*".

The illustration below describes the rate of the magnetic field attenuation of electric ranges. The data comes from 383 residences in the "1,000 house" Electric Power Research Institute (EPRI) study. Measurements were taken at three distances from the front of electric ranges with large front burners.



Radiant heat panels are liable to produce technologically unnecessarily high magnetic fields especially when the wiring generates a loop current, as indicated below.



Not generally known is the fact that dwellings have have electric field "hot spots". The table below, adapted from a 1993 Bonneville Power Administration study characterizes these:

location / device	**electric field readings** in Volts per Mete (V/m)
broiler	130
toaster	40
stereo	90
hallway	13
bedrooms	2 - 8
electric blankets	100 - 2,000

3.2 REVIEW OF RESIDENTIAL EMF SURVEYS AND OBSERVATIONS

In recent years there has been a growing interest among researchers worldwide to measure and to understand the nature of EMFs in housing. Most of the earlier research was motivated by trying to identify possible co-relations between epidemiological studies' results and the EMF conditions in residences of reported cases. Then, as public concern grew about EMF conditions, utilities were pressed to provide surveys, which in some cases, as in the **Canadian Electrical Association** (CEA) led to considerable databases and were reported. More recent surveys have attempted to co-relate relationships between field sources and indoor measurements and to provide neat research resources. Below are indicated recent surveys and their characteristics and average magnetic field results.

researcher	# homes	avg magnetic fields	notes
Kaune	29	1.41 mG	1994, Washington State, 24hr
Skotte		4.90 mG	1994, near transmission lines
Merchant		6.86 mG	1994, near transmission lines
London	249	0.70 mG	1993, Los Angeles County, over 2.68 mG
Yost	14	1.90 mG	1992, San Francisco protocol study
GE/EPRI	707	0.35 mG	1979-1992, utility employees
CEA	36	0.84 mG	1991, across Canada
Silva	86	0.80 mG	1989
Savitz	481	1.10 mG	1987 (over 2.5 mG for all cancers)

Preliminary results from a 1994-1995 Minneapolis/Saint Paul and Detroit area survey of residential EMF by a group led by **R. S. Banks** based on the arithmetic means of spot and 24-hour measurements data indicates that:

1) the seasonal effect is small yet significant -- elevated in the summer and winter, reduced in the spring and fall;
2) there is a significant diurnal trend, higher at lunch and dinner, reduced in the early afternoon;
3) the largest effects were due to regional location (Minneapolis higher *versus* Detroit)
4) the second largest single effect is a brick exterior, perhaps indicative of the period of construction and the presence of knob and tube electrical fitting;
5) dwellings with the highest Wertheimer-Leeper wire code had EMF levels much higher than homes with the lowest code;
6) there was no significant effect from air conditioners, secondary heating sources, although all but 3 units used primary gas heating.

An ***EMDEX*** (wearable EMF meter) project residential study of 39 utility employees done by **T. Dan Bracken** for the **Electrical Power Research Institute** found that residential personal exposure shows the greatest variability over time. With regard to housing characteristics, the decade of construction was the only factor that correlated with wire codes -- probably reflecting both the electrical code and electrical engineering related to the transmission and distribution systems of the period and the presence of knob-and-tube wiring in the premises of the dwellings.

Research conducted at the **Department of Occupational Health, Faculty of Medicine, McGill University** indicates that school building structures tend to attenuate the circularity polarized magnetic fields from transmission lines at a variable rate ranging from 0% to a maximum of 89% less than the external field - depending on the metallic structure nature, beyond the natural attenuation that comes with the distance.

Research conducted in over 100 residences in Canada by the **Planetary Association for Clean Energy** suggests than in the ordinary EMF environment, the Canadian house wall reduces the external magnetic field by about 10%, though some composite concrete or brick walls which have cavities can reduce fields by up to 25%.

Experience developed from previous surveys has raised several measurement-related issues.

For comparative measurement results, some researchers have tended to favour the three-axis magnetic field meters probably with the view of obtaining average field readings. Single axis measurements require a more cumbersome process of collecting separate readings with the pickup coil oriented in three perpendicular planes. The computation of the maximum from these readings is made by squaring them, adding the squares together, and then taking the square root of the sum.

The question of sampling strategy of the spot measurements has led some researchers to opt for a single reading taken at the centre of a room with normal appliance use for the time of measurement, under normal, "as is" power conditions. A 14-home pilot study, which led to the "California Protocol" developed with the purpose of developing a "simple measure of the ambient background" by a group of San Francisco bay area researchers found that the centre room value is not strongly affected by appliances. The same study found that "surprisingly" bed readings were elevated (near 2.5 mG) compared to other rooms and the homes were not randomly selected. The study concluded that a measurement protocol using centre room spot readings in connection with some daily activity may provide a reasonably fast and accurate assessment of residential personal exposure to ELF magnetic fields. In fact, the protocol was to serve correlation with biomedical case and epidemiological studies. This experience has strongly influenced the protocol applied in further EMF surveys.

On April 11, 1994, the **European Parliament Committee on the Environment, Public Health and Consumer Protection** released a session document, ***On combatting the harmful effects of non-ionizing radiation*** which saw the need for "a harmonized system for measuring and calculating electromagnetic fields and power densities in dwellings and workplaces so as better to monitor the exposure of the public and of workers." This same document prepared for the introduction of labelling and standard product information about fields generated by electrical household appliances as a function of distance and type of use. Areas requiring the adoption of specific standards (or regulations), according to the EP committee are: "a) exposure to radiation in the microwave range; b) work on display screens; c) the installation of electricity transmission and distribution lines; and d) the use of certain domestic electrical equipment." The committee rebuked the incongruity between the EP accepted maximum value recommended in Sweden for work on a screen and the 20 times value applied along the right of ways. It suggested a policy of imposing line corridors within which there would be a ban on all permanent activity and *a fortiori* any dwelling. The committe suggested minimal technical requirements (burial, twisted cables, specific materials) minimizing the fields produced, in accordance with the ALARA (as low as reasonably acceptable) principle.

3.3 ISSUES

At the onset of this project, **Canada Mortgage and Housing Corporation** was provided with starting picture – all the housing EMF research had already been done. This was the standard position of the experts at the electrical utility industry.

With this posture, outside experts insisted that housing re-design initiatives with EMF factors considered would not be fruitful. It was assumed that there was nothing one could do to reduce EMFs by design. Essentially, only the utilities had the tools to manage EMFs. An argument would run, "Yes, you can mitigate EMF in house but these are only 1/3 of the effect – what about the other 2/3rd which is caused by the distribution system."

Another issue raised was that the only EMF of concern is the power frequency 60 Hz magnetic field. It was not good nor credible research practice to investigate electric fields, transients, static fields, radio frequencies and microwaves, etc. .

With the due process of this study, it has become clear that the Electrical Code is actually very good. In most housing EMF error tracing and trouble-shooting procedures, it should be followed with care. Unfortunately, electricians are generally very poor on understanding grounding and rationale in field reduction (as well as safety) behind numerous Code requirements. Furthermore, electricians are not generally motivated to search and trace for *net currents* to the degree required in order to resolve housing EMFs.

4. FIELD SURVEY DESIGN

4.1 SCOPE AND PURPOSE OF MEASUREMENTS

4.1a Prior studies by CEA and EPRI

Some important and illustrative electromagnetic surveys of residential situations have preceded this project. An overview of these is in order in providing a background and reference to the results of this exercise.

The first major and relevant Canada-wide EMF housing study, conducted in around 1991 throughout 69 residences in 6 provinces was: ***Measurement of electric and magnetic fields***, conducted by the utility-sponsored **Canadian Electrical Association (CEA)** (Document CEA 2725 677 - 1991). A number of relevant conclusion and recommendations of that study -- applicable to residential EMF surveys -- were largely attended to in our exercise, namely:

1. Residential data should be analysed by distance from electrical facilities. Comparisons of the actual measurement data to wire codes may be useful.

2. A large base of residential data is needed to reduce some of the bias. Ideally, measurement sites should be selected randomly.

3. More analysis should be done with three power levels: "*off*", "low" and "high".

4. Comparison of levels in residences based on regions may be useful. Different regions may have different types of distribution systems, ground resistance, etc..

5. Levels could be compared between houses with different types of grounding systems. Some houses may use ground rods, while other houses are grounded to water pipes.

6. Seasonal fluctuation in field levels could be studied.

The Canadian Electric Association's study also recommended that: Residential EMF survey protocols could be refined to allow for a more detailed breakdown of residential EMF levels due to proximity of transmission and distribution facilities.

The CEA study also listed a series of general recommendations, including:

Future measurement projects should be more specific by concentrating on one electromagnetic environment at a time.

All environments could benefit from more data. However, the selection of EMF survey sites needs to be more random to reduce potential biases.

Other measurements protocols should be examined to look for a common approach that would make data from different studies more compatible.

The protocols should be refined by removing any items which are not important in the analysis.

Project protocols should be established and tested before initiating actual data collection.

The protocol and questionnaire of this exercise does in large part accommodate the lessons learned by the Canadian Electrical Association's study -- and the improvements it suggested.

Information about the distance and nature of relationship to electrical transmission and distribution systems and facilities was compiled whenever possible.

The method of discriminating and then selecting survey sites by community density, building material used, type of electrical utility servicing and finally by regional sorting, essentially provided a "random" EMF setting for each case. Most of the sites were originally unknown to the survey team and were suggested by advising team members on the basis of matching parameters. CMHC and Manitoba Hydro submitted their own special interest cases which turned out to be quite random as far as EMF situations are concerned.

Concern about grounding systems, soil resistivity, "*on*"/"*off*"/"low" power consumption, etc. are reflected in the protocol which was tested in 3 sites prior to application throughout all the ensuing EMF surveys, after amendment and consultation with experts.

The final protocol's data capture was made compatible with other EMF studies conducted to date to ensure comparisons with such studies.

The comments of the independent EMF researcher Karl Riley of the "1,000-home EMF survey" by the United States Electrical Power Research Institute (EPRI) were useful in shaping this exercise's procedures. His critique is found in his 1995 book, ***Tracing EMFs in building wiring and grounding*** (Appendix A: *Comments on the gaps in EPRI's 1000-Homes Survey, p. 97-8*). His main comments are:

> An article in the ***EPRI Journal*** of April/May 1993 told the story of the 1000-Home Survey of magnetic fields in a sampling of homes nationwide. The data on the article was actually based on an interim report on the first 707 residences. However, the median remained the same in the final report: 0.5 mG for all room spot measurements. 75 % of all residences surveyed were under 1.0 mG, and 1.7 mG was exceeded in the highest 10 % of the residences.
>
> The article lists sources of magnetic fields identified in the homes but contains this statement: "Normally, internal wiring was not a significant field source in homes". This differs from my own finding that internal wiring (miswiring) is a very significant source of elevated magnetic fields in the home. If wiring in homes were correct "normally" I would agree, but it is an unusual and pleasant surprise when I find a building which has been wired correctly in all the branch circuits.
>
> How is it that EPRI missed this source? The answer became clear when the protocol was examined. Since the engineers in charge of the study were seemingly not aware of the wiring error as a major source of fields when they set up the study they did not design a protocol which would detect it.
>
> First, when their measuring teams entered a home they did not change the electrical usage: they took the house as they found it no matter what time of day they entered. This means that during the day they would not have seen the magnetic fields from incorrectly wired circuits simply because the circuits were not in use. Lights are generally *off* in single family houses in the day time. The magnetic fields the family may be exposed to from incorrect wiring will show up only in the evening and morning when the family is at home. At this time more appliances are also in use as well as exterior lighting.

Secondly, the measuring teams which entered the houses were retired couples who received some training as to how to use the gaussmeters but who were not expected to have technical understanding of wiring circuits nor were they authorized to open electrical boxes to search for sources.

Thirdly, when the engineers back in the office analyzed the collected data, even if the circuit with a net current had been activated at the time of measurement, all they would know from the data was that there was a linear source nearby. This was evidently than ascribed to the only known line source categories they had to choose from: knob-and-tube, neutral on water pipes, and 3-way switch wiring. Without doing some trouble shooting at the sight, they had to guess. For this reason the EPRI data on internal magnetic field sources has to be considered unreliable.

4.1b Characteristics of survey's data

In this survey, 60 Hz (with harmonics and oscillation content) magnetic and electric fields are measured and their source of emission identified in three EMF environmental states:

1) the "as-is" electrical power usage condition encountered at start of survey;

2) the "all-power-*off*" situation, labeled throughout the report as *"off"*

and finally in the

3) "all-power-*on*", labeled as *"on"*.

These measurements are conducted: 1) in the environment external to the residence, (usually at 4 corners of a lot, then at the outside perimeter of the structure, with spot readings for identifiable sources of emissions such as fixtures and services, as required); 2) in the internal environment (4 corners per room + centre with spot readings for sources such as appliances, "hot spots").

This data collection and consequent evaluation is helpful in determining the choice and potential cost of appropriate EMF mitigation and/or reduction exercises for electrical power frequency range electric and magnetic fields. The data collection protocol permits EMF characterization of housing by various parameters (construction age, materials, density conditions, etc.) for further analysis of potential interest to housing authorities, residential construction and servicing trades.

The "all-*on*" state measurement partially offsets the CEA's concern for the seasonal variation of power consumption with regards to the internal and neighborhood wiring/net current conditions – for maximum consumption periods. However, for the transmission and distribution sourced fields impinging on the internal EMF conditions, it is possible to model such field intensity differentials on the basis of the CEA and EPRI findings onto the data captured in this exercise.

Purpose of EMF measurement in housing should include all elements that concern EMF in housing and it is directly connected with measurement protocol and choice of measurement equipment.

Though this exercise's survey sample is small, the data captured should be conducive to a descriptive of national characterization of EMF for the 60 Hz (with harmonics and transients), static magnetic and radiofrequency/microwave as found in Canadian dwellings. On the other hand, the small sample size should not be necessarily indicative of the actual proportion of EMF field conditions to be found across the nation.

The set of "typical" residences across Canada have been measured which demonstrate various construction modes and practices, ages groups, geographical distribution.

These residences indicate a wide variety of situations that define the EMF situation in Canadian, with no intentional bias.

The survey data is set up in such a way that it can be directly compared with other survey data at a later date. So far, the research of EMF housing has included measurements of site "as is" or with some additional power consumption demands.

To interpret the influence of sources exterior to the house and house sources, the measurements should be taken for two characteristic cases: power "*off*" and high power (all appliances turned "*on*"). The first case enable to note the influence of EMF from outside the residence. A usual source is power lines, either transmission with low dynamics and distribution lines with high dynamics. However, due to the nature of utility's multi-grounded neutral distribution system, neutral return current can also be found along water mains, phone lines, cable TV lines, ground rods and thus these can become secondary sources of EMF impinging on the internal environment.

The all-power-"*on*" state may add new EMFs. These fields may originate from the residence's wiring characteristics and include such sources as "knob and tube" wiring, multi-locational switches, corroded groundwire-water main contact, improper panel/sub-panel neutral wire installation, physical contact between water, gas and/or air duct conduits and grounding wires – including those which may be located inside appliances such as washers, ice-making refrigerators, gas stoves which may provide such infrastructural contact points. These new fields may be much greater larger if there are wiring errors, knob and tube wiring or if there is a higher demand of the already-mentioned utility's multi-grounded neutral distribution system.

Additionally, there are EMFs originating from appliances and devices as point emission sources which are activated when these are put "*on*".

In this study, electric and magnetic field measurements were taken throughout residences in each room or zone, (with due notation of harmonics and transient content). Representative peripheral and lateral profiles were undertaken when these were deemed to describe special and significant conditions. Neutral return, grounding wire, water main currents (with harmonics content) were measured over time, usually over periods of about 30 minutes. Variations of the static magnetic fields were surveyed in baseline samplings, and for zones occupied for extended periods of time such as beds. All sites were verified for the level of broadband radio and microwave frequency power density impinging from the environment and from appliances, usually microwave ovens.

Due to the small survey size, all measurements were undertaken by the same people, using the same calibrated instruments and following the same protocol.

4.2 PROTOCOL

The study's scope and purpose of measurement determined most of the protocol and procedure. The collection of basic information related to the residence is contained within the first three pages. This data is elementary and is serviceable for elaboration in future studies as well as in the cross-referencing and compilation of current measurements. The data includes: type of residence, occupant data, building life, external and internal utilities, grounding characteristics, residence size and materials, and appliances. Provision has been made for notes resulting from conversations with the occupants and for plans.

The plan is a sketch of main rooms in the residence by floor, as well as locations of the power panel, main water pipe, gas pipe, ground wires of TV and phone cable. The outside is very important to mark approximate distances to nearby power lines as well as supply of utility, water and gas for house. Photographs were taken of the residence and in many cases, of the opened electrical panel. The panels were opened to probe the current relationships between the ground wires and water and gas pipes, TV and phone cable, neutral conductor, ground rods, etc. and to verify if there were any wiring errors associated with electromagnetic fields measured in the premises. Where warranted, wiring was analyzed from the panel to zones of special concern to check for possible contact points between utilities and related notes would be taken during the survey as commentary.

The actual measurement procedure, involving at least two team members, but usually three or four individuals, would be as follows. Electric and magnetic field measurements would be taken during a slow walk-around throughout. Notes were taken of the field results in the centre and all the corners of each room (at a height of one meter above the floor), along with observations of "hot spots". Though the measurements were generally conducted for the 60 Hz frequency, a check was conducted to determine any significant influence of power frequency harmonics. While these results were being captured, the clamp - on ammeter would have been placed around the main ground wire of utility panel in record mode to collect maximum, minimum and average values of current. The above procedure would be conducted for the "as is" situation. All of these steps were repeated for the "all power *off*" and the "all power *on*" states. Current measurements through neutral conductor, main water pipe on the entrance of the house and other ground wires were added when feasible.

The magnetic fields of basic appliances in the rooms were measured at distances of 10 and 50 cm in at least the "*on*" position.

Outside or around the residence both the electric and magnetic fields were measured. Notes were taken of EMFs at the corners of the structure's perimeter, and where applicable, the corners of the lot, as well as potential "hot spots" (power supply cable, water pipe outside, etc.). As circumstances might have required, a lateral profile of readings would be made to the nearest transmission or distribution power line.

The geophysical/static magnetic field observations would be taken as representative of the variations to be found for the entire site, with a additional attention for specific measurements for locations where the occupants use over extended periods of time, such as bedsites. Notes would taken of the baseline levels as well as of the percentage of variation or disturbance between maximum and minimum levels divided by the area surveyed in bedsites, with comments for the verified cause of major disturbance when such has been determined to exist.

Notes were taken for any radiofrequency and microwave power density above .01 milliWatt per square centimeter emissions identified in the environment impinging on the residence. Likewise all microwave ovens were tested for their level of leakage.

The original pages of the measurement protocol are appended.

4.3 CHOICE OF RESIDENCES SURVEYED

Over 50 candidate residences were identified with due discretion by the Study members across Canada in anticipation of filtering a "representative" cross-section of Canadian housing stock composing of, at first, 25 houses to be surveyed. CMHC added five more units to the list and **Manitoba Hydro** accounted for another 3. The remainder of additional units were added on courtesy of the Association to ensure a broader capture of EMF conditions useful. (It was always recognized that the small sample of would probably provide no real statistical value other than an useful compilation of electromagnetic conditions and their general remedial potential). Although some houses were identified almost immediately for surveying shortly after start, others took many weeks, to be confirmed for proper survey appointments.

It was anticipated that the houses surveyed would fall into the following classifications:

Urban, high density, multiple unit /brick; concrete
Urban, average density, multiple unit *(including urban infill)* /brick; stone; wood
Urban, average density, single unit *(including older home retrofit)* / brick; stone; wood
Suburban, high density, multiple unit, overhead utility *(including older home retrofit)* / brick, wood, metal
Suburban, high density, multiple unit, underground utility / brick, wood
Suburban, average density, multiple unit, overhead utility / brick, wood, metal
Suburban, average or low density, single unit, overhead utility / brick, wood, metal
Rural/isolated wilderness / *stone, brick, wood, metal*
Mobile home, suburban /metal
Mobile home, rural / metal

This listing was not considered to be conclusive and was subject to the deliberations of the Study team members, practical conditions and the suggestions of the CMHC Research Division. The CMHC requested inclusion of special projects sites developed by the Research Division, such as the ***Vancouver Healthy House*** and two units serving disabled residents. **Manitoba Hydro** selected and proposed three units for surveying, one of which served as a mitigation exercise.

One factor which determined the removal of a house from the survey list was the presence of erratic static magnetic field conditions, of geologic nature. Such conditions were considered to alter the value of survey readings and to steer research results away from representative Canadian housing conditions.

A determined effort was made to assure a nation-wide distribution of surveyed houses. Units were surveyed in British Columbia, in the Prairies (Manitoba and Saskatchewan) and in Central Canada (Ontario and Quebec).

Necessary and possible efforts were made to assure that selection of houses and the actual conduct the surveys were tactful and polite and occupants would be able to gain access to the survey results of their residence, while retaining confidentiality as to identification of their case file.

In addition, the selections were deemed to provide an opportunity for the collection of potentially useful information such as, types and materials of conduits (water, air vents) used, nature of grounding, nature of fixtures related to the entry of power supply. Based on prior field experience, cross-tabulating such data with actual measurements was considered to permit the development of useful observations that would permit the

CMHC Research Division to focus in greater detail in further work and/or in its advisement to consumers.

4.4 INSTRUMENTATION AND CALIBRATION

The following instruments were used in this study's surveys:

1) three axis magnetic field instruments
2) single axis hand-held magnetic field probes
3) clamp-on ammeter
4) electric field strength meter
5) instrument for measuring radio and microwave power density
6) instrument for measuring static magnetic fields
7) (ELF-MW) broadband audio EMF sensor device

The three axis magnetic field instrument measures the magnetic field along three orthogonal axes. The ***Field Star*** (Dexsil Corporation) was used for measuring the magnetic fields in characteristic points of house as well as magnetic field of some appliances (such as stove, oven, toaster, electrical water heater, etc.). The *Field Star* may be used otherwise but because of specific measurements of EMF in housing it was only used in this way.

A gaussmeter which measures only 60 Hz may miss up to 50% of the power frequency magnetic field and may fail in measuring the magnetic ELF field from some VDTs (video display terminals), whose ELF frequencies range from 15 to 90 Hz and higher. Some devices produce harmonics – such as computers, fluorescent lights, dimmer switches, motor controls or runs and in those cases, we used instruments with frequency response up to 1 kHz (within +/-5%, based on IEEE Standard 644-1987).

The ***AC Milligaussmeter - Model 42 B-1*** (Monitor Industries) can measure magnetic field in frequency response up to 1 kHz (1,000 Hz). The instrument has two modes, flat and linear, which gives the possibility for identification of harmonics. For the observation of the waveform and the frequencies of the EMF we have used the ***E.L.F. Laptop Spectrum Analyzer*** Model IER-219; IER-225 and IER-230 (Integrity Design & Research Corporation).

It is much easier to trace EMFs in housing with instruments with single axis hand-held magnetic field probes. Instruments used for precise measurements of electric field are very expensive. ***Electric field adapter*** Model E-100 (Magnetic Sciences International) was beneficial although its precision is not necessarily in accordance with IEEE Standard 644-1987. It was good enough within its estimated maximum range of error to permit critical identification of sources of electric field. The same is true for the instrument for the measuring radio and microwave power density. The ***Fluke 33 true RMS clamp-on ammeter*** has the useful function of recording maximum, minimum and average in fluctuating line, which is mandatory when measuring currents of the power utility's multi-grounded neutral distribution systems. True RMS will also give more accurate measurements in a harmonic environment.

The following are the specifications of instruments used for the study's surveys, given, in the appendage, with the description of instruments and their procedure for the use, technical data, accuracy and date of calibration.

4. 4a List of instruments

AC Milligaussmeter - Model 42B-1 - **Monitor Industries**

AC Gaussmeter - Model MSI 20/25 - **Magnetic Science International**

60 Hz Magnetic Dosimeter - Model IDR- 109 - **Integrity Design & Research Corp.**

Field Star - **Dexsil Corporation**

Trifield Meter - **AlphaLab**

Geo-magnetometer - Model BPM 2001 - **Bio-Physik L. Mersmann**

Electric field adapter - Model E-100 - **Magnetic Sciences International**

Clamp-on ammeter - Model 33 Current Masters - **Fluke**

Clamp-on AC/DC current probe- Model Y8100 - **Fluke**

E.L.F. Laptop Spectrum Analyzer - Model IER-219, IER 225, IER-230 - **Integrity Design & Research Corp.**

5. TEST RESULTS AND ANALYSIS

The number of dwellings surveyed was 36, leading to 43 surveyed cases -- the additional 7 refer to mitigation exercises and to multiple cases such as separate units in one apartment buildings. 338 rooms were surveyed. More than 10,000 data were collected, including measurements, replies to queries, observations.

The rather small sample is very rich in data. All measurements were done with the same crew and instruments, thereby avoiding potential for error and mistakes in the data collection and analysis. Each dwelling was surveyed by at least 3 individuals for at 4 hours just to collect the minimum data required by the protocol. It was not possible to capture the whole range of "hot spot" measurements for all dwellings. Nevertheless all "hot spots" that became immediately observable were in fact measured and in all mitigation cases, all hot spots were duly registered. The very fact that "hot spots" data were tabulated accounts for, in part, the large deviation in fields measured, especially in corners (due to the presence of appliances, wiring, pipes, ground wires, etc.).

For analysis purposes, it would have been convenient to arbitrarily remove all "hot spots." One could cut-off magnetic levels higher than 2mG. Naturally, with such a procedure, the results would become more "coherent", in accordance with practices done by other researchers. It remains to be seen whether this method of discriminating data does in fact reflect the best data analysis procedure. Occupants of dwellings do in fact live in such contradictory, highly deviatory, EMF environments next to numerous "hot spots" that influence the actual distribution of magnetic fields throughout rooms and in some instances, entire houses. Ultimately, occupants should know the nature and location of "hot spots" in order to be able to either undertake remedial physical action (such as a mitigation procedure) or to alter their lifestyle with prudent avoidance in mind. If we care to perceive EMF in housing this global way then, naturally, each residence must be viewed as a separate and unique environment.

Consequently, it should be emphasized that the following analyses are preliminary. With this "rough data" we have obtained, in some instances, standard deviations of over 250% in some statistical calculations. The purpose of these comparative exercises was merely to indicate the nature of EMF correlations.

5.1 Baseline data from 338 rooms

Measurements were taken of the magnetic and electric fields at the centre of the room and in the four corners, in 3 circumstances: "all power *off*", "as is" and finally, "all power *on*".

The average fields are described in the table below:

Averages of magnetic flux density, 338 rooms
in milliGauss / sample size

location	"All power *off*"	"As is"	"All power *on*"
centre of room	**1.31**/*309*	**1.49**/*325*	**2.09**/*306*
corners	**1.56**/*1280*	**2.28**/*1232*	**5.44**/*1212*
average, all readings	**1.43**/*1589*		

There is a similarity in the fields in the comparison of measurements taken during the "as is" condition in centre-of-room measurements and those for all room centres with all four corners in all power "off" situation (i.e.: 1.31 versus 1.49 mG -- about 4.2% variation). In other words, the centre-of-room magnetic field level, generally less affected by appliances and indoor wiring reflects the predominance of outdoor conditions supplemented by whatever ground currents and net currents which may be circulating indoors through conductors. Therefore, these results confirm the utility research view that magnetic fields found in the centres of rooms generally reflect external EMF conditions, namely, distribution supply + influence of the multi-ground system.

The average magnetic field conditions at the corners in both the "as is" (2.28 versus 1.49 mG -- 1.5 X) and in the "all power *on*" (5.44 versus 2.09 mG – 2.6 X) situation are higher that those at the room centres, probably reflecting the influence of appliances and wiring.

The magnetic field levels in the centre of rooms during the "all power on" are 46.2% higher than in the "all *off*" state: 2.09 mG. This significant increase may be attributable to the influence of room corners' activity. This information is novel and has not been captured in other comparable surveys. What is significant for home occupants that the both the 2.09 (centre) and 5.44 mG (corner) averages may be more realistically representative of the lifestyle exposure of occupants during the hours of highest electrical consumption, at noon and in the evening -- in the kitchen/dining room.

The "as is" levels may be considered to be representative of the way people tend to consume electrical power in Canadian residences. Recent U.S. domestic means range from 0.60 mG to 2.70 mG and probably reflect various climatological, consumer parameters. By contrast, British means for centres of rooms in 50 dwellings reported in 1995 by A. W. Preece ranged from only 0.08 mG to 0.15 mG -- with the an all power "on" mean of about 0.20 mG. Even the British study noted a big discrepancy in actual average recorded personal exposure of between 0.67 to 0.75 mG (about 6X more than room centre levels), reflecting the natural usage of space near room corners in daily living. A factor for the lower U.K. levels could be the higher voltage system (220 V system) that reduces the amperage and its resultant magnetic field)

Standard deviations are notably high, reflecting the great variation in conditions in every dwelling and suggesting that it is altogether difficult to characterize in "one snapshot" electromagnetic fields conditions in Canadian housing, especially when there is no particular bias, such as proximity to power transmission and distribution lines, location, construction age and materials, etc. Additionally, the greatest deviations occur at the corners, during the "all power *on*" state, when all kind of appliances are operational.

Standard deviations for room magnetic flux density measurements, 338 rooms

location	"All power *off*"	"As is"	"All power *on*"
centre of room	*1.31 mG*	*1.49 mG*	*2.09 mG*
standard deviation	**1.68**	**1.87**	**2.67**
corners	*1.46 mG*	*2.28 mG*	*5.44 mG*
standard deviation	**2.66**	**5.15**	**27.35**
average, all readings	*1.43 mG*		
standard deviation	**2.49**		

Average magnetic field readings vary according to room type. In the "all power *off*" the highest levels were measured in kitchens and the usually adjacent dining rooms. This may be because electrical panels are often installed in proximity to these. Family rooms are in large houses where levels tend to be lower.

Room type	*"off"/mG*		*"on"/mG*		*"as is"/mG*	
by sample size	**ctr**	**corner**	**ctr**	**corner**	**ctr**	**corner**
Basement	**1.23**	**1.24**	**3.09**	**6.00**	**1.70**	**1.91**
63 units	*53*	*212*	*55*	*220*	*58*	*215*
All Bedrooms	**1.16**	**1.39**	**1.56**	**6.06**	**1.29**	**1.98**
89	*84*	*332*	*86*	*342*	*87*	*340*
Child Bedroom	**1.19**	**1.41**	**1.50**	**7.45**	**1.34**	**1.81**
48	*45*	*180*	*47*	*188*	*47*	*184*
Master Bedroom	**1.12**	**1.36**	**1.64**	**4.39**	**1.24**	**2.19**
41	*39*	*152*	*39*	*156*	*40*	*152*
Kitchen	**1.61**	**1.73**	**2.68**	**6.13**	**1.79**	**3.85**
43	*40*	*160*	*41*	*160*	*40*	*164*
Dining	**1.63**	**1.85**	**2.15**	**4.09**	**1.72**	**2.42**
31	*28*	*112*	*29*	*116*	*30*	*112*
Living	**1.56**	**1.71**	**1.90**	**4.16**	**1.51**	**1.98**
38	*36*	*140*	*35*	*140*	*37*	*140*
Family	**0.80**	**0.92**	**1.46**	**3.26**	**0.94**	**1.40**
12	*12*	*48*	*12*	*48*	*12*	*48*

Nota bene: The smaller type size numbers represent sample size for each value

In the "all power on" state, basement centres have the highest average room centre reading (3.09 mG), reflecting the practice to locate panels, furnace, water heating, air conditioning, humidifier, grounding wire, etc. near the core. Kitchens, due to their small size and many appliances also have an elevated level (2.68 mG) and they tend to pollute the dining room (2.15 mG).

The corners of children's bedrooms have the survey's highest average fields (7.45 mG) -- in the corners. This is attributable to devices such as computers, TVs, clock radios, entertainment centres and reading lamps which tend to be placed in corners in these rooms. The transformer sourced emission characteristics of such devices tends to be of high attenuation rate and thereby does not affect the centre of room value which, at 1.50 mG, is almost the lowest "all power *on*" average value surveyed. Children's bedrooms are usually small and the actual occupant exposure value may reside somewhere in between the corner/centre of room average.

5.2 Community density

Community density characteristic has been subdivided into three categories, reflecting estimated population densities: 500+ /hectare, 100 - 500/hectare and less. This breakdown may indicate land use differences in electrical power distribution, cohesion of building structures, and even impact on construction practices.

Density: "as is" state	**Centre of rooms** mG/ *sample*	**Corners** mG/ *sample*
High / *10 units*	**2.02** / *69*	**2.52** / *260*
Medium / *19 units*	**1.76** / *135*	**2.89** / *504*
Low / *14 units*	**0.87** / *120*	**1.53** / *480*

Density: "all power *off*"	**Centre of rooms** mG/ sample	**Corners** mG/ sample
High / *8 units*	**2.05** / *51*	**2.33** / *328*
Medium / *18 units*	**0.72** / *123*	**1.94** / *492*
Low / *15 units*	**0.56** / *119*	**0.59** / *487*

The EMF magnetic field levels are consistent with density in descending order, reflecting the environmental EMF intensities associated with land use. An exception to this orderly statistical distribution the "as is" condition found in the corners of medium density structures. The "hot spots" in the corners may represent the lifestyle and purchasing power factor of greater usage of appliances and/or the impact of wiring.

5.3 Community type

The location of the surveyed unit has been set in three categories of communities: urban core, suburban sprawl context and the rural/wilderness milieu. Again the EMF magnetic fields levels are consistent with the built-up density in descending order, continuing to reflect the environmental EMF densities associated with land use. However this time there is no anomaly associated with corner measurements formerly attributed to the consumer lifestyle factor.

Community: "as is" state	**Centre of rooms** mG/ *sample*	**Corners** mG/ *sample*
Urban / *15 units*	**2.12** / *104*	**3.00** / *393*
Suburban / *21 units*	**1.39** / *171*	**2.21** / *449*
Rural / *7 units*	**0.54** / *120*	**1.15** / *204*

5.4 Material of construction

The results of EMF field intensity by principal material of construction suggest that the dwellings with lowest fields tend to be built in wood, stone and concrete while those more liable to higher EMF are brick and metal structures. It is interesting that the finding that exterior brick dwellings have by far the highest EMF levels is consistent with the 1995 **R. S. Banks** Detroit/Minneapolis survey results, perhaps indicative of the period of construction and the residual presence of knob and tube electrical fittings. The high corner levels found in metal units may be attributed to the mobile houses which are very compact.

Material type: "as is" state	**Centre of rooms** mG/ *sample*	**Corners** mG/ *sample*
Brick / *8 units*	**2.56** / *68*	**3.64** / *272*
Concrete / *5 units*	**1.46** / *31*	**1.66** / *105*
Metal / *4 units*	**1.40**/ *29*	**2.97** / *116*
Stone / *2 units*	**0.90** / *22*	**1.46** / *88*
Wood / *19 units*	**0.84** / *133*	**1.57** / *496*

5.5 Overhead / underground electrical distribution

Underground electrical distribution tends to provide a 23 % lower environmental EMF impact compared to the overhead mode. This result is generally consistent with EPRI "1000-home" survey findings.

Distribution: "as is" state	**Centre of rooms** mG/ *sample*	**Corners** mG/ *sample*
Overhead / *27 units*	**1.62** / *199*	**2.54** / *754*
Underground / *15 units*	**1.25** / *116*	**1.82** / *441*

5.6 Structure age

Structure age has been differentiated as "new" and "old" under 2 groupings: either as pre/post-1960 or pre/post-1970. The reason for the overlap for the 1960 - 1970 threshold is to be able to compare with other survey results suggesting the 1960s were the decade showing a transition in EMF results. The same relationship in lower EMFs in newer dwellings – usually serviced with newer distribution systems under the aegis of updated electrical code requirements – reemerges.

Structure age: "as is" state	**Centre of rooms** mG/ *sample*	**Corners** mG/ *sample*
Pre - 1960 / *16 units*	**1.97** / *126*	**3.09** / *464*
1961 - / *27 units*	**1.19** / *199*	**1.80** / *773*
Pre - 1970 / *22 units*	**2.05** / *166*	**2.86** / *655*
1971 - / *21 units*	**0.90** / *158*	**1.73** / *632*

5.7 Single/multiple unit

According to this analysis, single units have almost half of the EMFs found in multiple units, both in the centre of rooms and along the walls. Multiple units have been found in apartment buildings and row houses.

Single / multiple: "as is" state	**Centre of rooms** mG/ *sample*	**Corners** mG/ *sample*
Single unit / *22 units*	**1.18** / *174*	**1.72** / *660*
Multiple unit / *16 units*	**2.19** / *110*	**3.35** / *412*

5.8 Dwelling size

Large residences, with over 250 square metres floor area have by far the lowest EMF. Small to Little sized dwellings (less than 60 to 90 square metres) have a combined average of near 3 mG. Average sized dwellings, probably the most common housing size in Canada, have a combined average of near 4 mG. Medium sized housing have a combined EMF of just above 2 mG.

Dwelling Size *(sqm)*	*"off"/mG* ctr	corner	*"on"/mG* ctr	corner	"as is"/mG ctr	corner	COMBINED average
Small	2.13	2.17	2.09	5.16	1.79	2.35	**2.98**
< 60 sqm / 2	*9*	*36*	*9*	*36*	*9*	*36*	*135*
Little	1.00	1.34	3.65	6.08	1.47	2.97	**3.18**
60 - 89 / 4	*29*	*116*	*29*	*116*	*29*	*116*	*580*
Average	1.63	1.86	2.22	8.72	1.63	2.44	**3.80**
100 - 150 / 12	*69*	*276*	*69*	*276*	*81*	*288*	*1059*
Medium	1.20	1.45	1.60	4.06	1.30	1.91	**2.25**
153 - 250 / 5	*46*	*184*	*46*	*184*	*46*	*184*	*690*
Large	0.34	0.35	1.37	2.72	0.71	1.46	**1.44**
> 250 sqm / 5	*37*	*144*	*48*	*180*	*49*	*184*	*643*

Nota bene: The smaller type size italic numbers represent sample size for each value

5.9 Electric power consumption

No significant relationship between electric power consumption and EMF is identified in this analysis, consistent with the EPRI "1,000 Home" survey results. However, the medium power consumption tends to show higher EMF levels, suggesting a weak relationship between lower consumption and lower EMF. The same result (2 mG) for the high consumption may be overshadowed by the likely larger dwelling size factor.

KwH	"off"/mG		"on"/mG		"as is"/mG		COMBINED
	ctr	corner	ctr	corner	ctr	corner	average
Low	1.12	1.16	1.66	3.45	1.13	1.73	**1.93**
< 28 KwH / 7	*41*	*163*	*41*	*163*	*54*	*175*	*637*
Medium	0.71	0.81	1.51	9.43	0.96	2.10	**3.50**
22 - 46 / 5	*43*	*172*	*43*	*172*	*43*	*172*	*645*
High	0.74	0.85	1.84	3.33	1.15	2.08	**2.01**
> 55 / 4	*30*	*120*	*39*	*156*	*40*	*160*	*545*

5.10 Gas supply

No relationship between gas supply services and EMF are identified in this analysis.

Gas Supply	"off"/mG ctr	"off"/mG corner	"on"/mG ctr	"on"/mG corner	"as is"/mG ctr	"as is"/mG corner	COMBINED average
Gas	1.19	1.26	2.45	4.47	1.52	2.19	2.46
18	149	596	149	595	140	560	2189
No Gas	1.16	1.46	1.66	6.67	1.32	2.37	3.10
21	124	496	135	534	147	571	2007

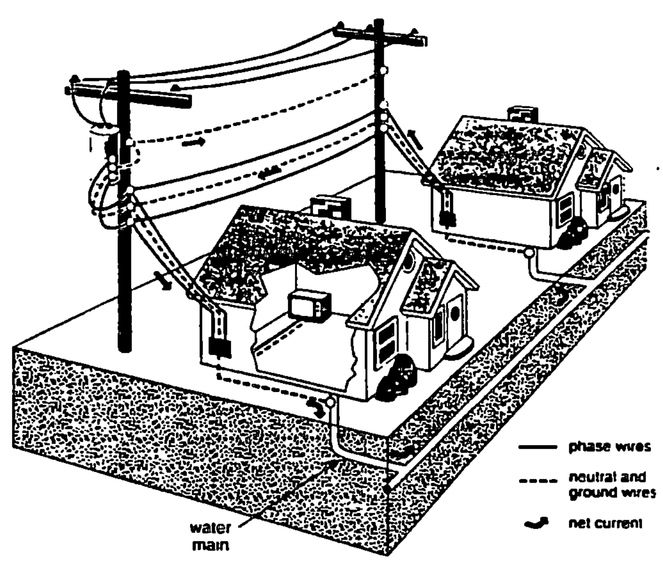
5.11 *Net currents*

Net current can travel in the gas supply piping, in water pipes, in the grounding wire, telephone cable and cablevision cable. They are a result of the multi-ground system. I Amp (A) of current at 1 metre causes a 2mG field. Their role in generating EMF is shown in this comprehensive tabulation:

Net Current Multiground Factor	"off"/mG ctr	"off"/mG corner	"on"/mG ctr	"on"/mG corner	"as is"/mG ctr	"as is"/mG corner
> 1 Amp *(all)*	0.91	0.98	2.27	6.07	1.14	1.87
in any grounding / 17	142	568	151	604	152	608
> 1 Amp *(good)*						
in any grounding but	0.32	0.32	1.06	2.25	0.48	0.73
good placement / 5	41	164	50	200	51	204
> 1 Amp *(bad)*	1.14	1.24	2.84	7.89	1.45	2.42
without the 5 good / 12	102	404	102	404	102	404

The above 17 dwellings had at least one grounding wire with a current of at least 1 Amp. Once 5 cases are cut-off due to good electrical practice of locating main panels near to water mains or grounding rods, the remaining 12 stand out – with even higher EMFs. Good placement enables potentially bad EMF cases to register "as is" center of room EMFs of only 0.48 mG and comers of 0.73 mG, underlining the critical role of badly placed grounding wires in influencing EMF levels inside Canadian housing.

The *net current* occurrence house has the same "as is" room centre level as its baseline Canadian "as is" counterpart: 1.45 *vs.* 1.49 mG. The insidious nature of *net current* emerges when one compares with the "all power on" state for these houses and notes the 36 % jump to 2.84 mG in centres with a related 45% increase to 7.89 mG for comers. This is because *net current* can travel ubiquitously inside and outside the residence. Even in good panel placement cases EMFs augment considerably, indicating how important it remains for occupants to know their "hot spots." As indicated in section 5.20, 10 "low EMF dwellings" have been identified. Even for these, *net current* plays a key role.



Magnetic fields also come from grounding system, power lines and *net current*.

Net Current: "Low EMF" homes	*"off"/mG* ctr	corner	*"on"/mG* ctr	corner	*"as is"/mG* ctr	corner
With *net current*	0.23	0.24	0.77	2.37	0.40	0.66
10 units	*81*	*324*	*91*	*364*	*91*	*364*
< 1 Amp *net current* only	0.14	0.14	0.31	2.46	0.29	0.56
5 units	*41*	*164*	*41*	*164*	*41*	*164*

5.11a Current in the gas supply pipes

In all 16 units the main gas pipes did not carry any current -- in both "all power on" and "all power *off*" states. However, an in-house current loop was found going through some gas pipes. In Case # 11, a 0.50 A current loop developed inside the residence between the gas stove and the water heater. The origin was traced to an electrical clock on the gas stove. In Case # 24, a 0.02 - 0.03 A current loop in the gas pipe was identified between a gas furnace and a gas water heater. The mitigation procedure involved the insertion of a plastic or rubber tubing on the furnace, gas stove or water heater.

5.11b Current in the Neutral conductor during the "all power *off*" state

Theoretically, there should be no current in the neutral conductor when no power is consumed. However, the presence of current therein indicates the presence of some net current in the house/outdoor interface. Occasionally, the presence of current in the neutral conductor constitutes a source of EMFs, depending on the disposition of the cable in the general electrical layout of a dwelling. If the neutral wire goes directly to the service for a short distance, exposure to inhabited areas is shortened likewise.

In the 26 units measured for 3 minutes in the "all power *off*" state, the average current coming from the outside via neutral conductor would vary between 0.00 A to 1.03 A (Case # 34) and 2.14 A (Case # 13). These dwellings would experiences current maxima of 1.22 A and 2.43 A respectively -- about 20% more than their averages. Peaks were registered in another 2 sites, 1.57 A (Case # 2) and 2.67 A (Case # 17). 14 units -- more than half of those measured -- had currents of less than 0.50 A, most near the 0.10 A range.

5.11c Current in Grounding wire during the "all power *off*" state

Grounding wire current in "all power *off*" state was measured in 30 sites for 30 minutes. 8 sites had grounding rods, where current during the "all power *off*" state was marginal, 0.1 A. Current was higher when grounding was availed through the water main system.

Generally, the current levels were negligible, however 2 dwelling units had average currents of 0.88 A (Case # 16) and 1.00 A (Case # 9). Case # 16 had a peak of 1.07 A. Other elevated maxima were found in 3 more cases -- 1.18 A (Case # 33A, prior to a mitigation), 2.72 A (Case # 17) and 3.03 A (Case # 34).

5.11d Current in the water main in the "all power *off*" state.

Current in the water service was measured in the 17 sites where it was possible to accede to the fixture. In 2 sites, the average currents were 1.00 A (Case # 9) and 1.99 A (Case # 13), where the maximum value measured was 4.40 A. There were 2 other cases of 0.48 A (Case # 33A) and 0.55 A (Case # 17). The remaining cases had either null or less than 0.10 A current. Resulting indoor EMFs depend on panel/water main configuration.

5.11e Current in the Grounding wire during the "all power *on*" state

Current in the main grounding wire during the "all power *on*" state was measured in 30 locations. It was high in 17 or 2/3rd of the cases examined – ranging from a 1.12 A (Case # 26) up to 17.15 A (Case # 17), 22.55 A (Case # 19) and 27.84 A (Case # 11). In these units, the greatest current going through the grounding wire during the "all power *on*" state was 7.35 Amps, while the average was 4.36 A.

The fluctuation of current level is considerable. As very few of the dwellings were measured during the peak electrical consumption and dwelling occupancy periods, the real peaks and averages could double during such hours. Considering that in some dwellings the EMF associated with grounding wire can stretch across inhabited zones, such very wide amplifications become significant to the occupants.

5.11f Current in the water main in the "all power *on*" state.

The use of electrical power in the same 17 dwellings triggered current through the water main. Notable average current values were measured in 6 sites, ranging from 0.98 A to 5.78 A (Case 33A, before mitigation, which had a maximum peak of 6.85 A), while the average value was 3.28 A. However, maximum current surges were also monitored in another 3 locations: 1.01 A (Case # 35), 1.23 A (Case # 2) and 5.71 A (Case # 17). Essentially 7 out of 17 dwellings (or 41 %) had significant current in the water main, indicating the prevalence of the problem in Canadian housing stock. *None* *of the remaining housing units (which all use grounding rods) had significant current in the water main.*

5.11g Current in the TV cable and telephone grounds

Current was measured in the TV cable and telephone ground only during the "all power *on*" and "*off*" states in 22 locations. In "*off*" states, only 2 sites had significant values: 0.86 A average - 0.89 A maximum (Case # 34) and 1.02 A average - 1.35 A maximum (Case # 35). Some sites had around 0.5 A (Cases # 06, 14. 17 and 24).

5.12 Outdoor EMF

Outdoor powerline magnetic fields can predominate indoor EMF levels. In 10 cases, outdoor fields were higher than 2 mG and their influence on indoor EMF is pronounced.

Outdoor EMF:	***"off"/mG***		***"on"/mG***		***"as is"/mG***	
≥ 2mG	**ctr**	**corner**	**ctr**	**corner**	**ctr**	**corner**
≥ 2mG	**2.95**	**3.40**	**3.48**	**6.61**	**2.99**	**3.93**
10 units	*76*	*304*	*76*	*304*	*76*	*304*

The impact of the outdoor levels is more clearly observed when the 3 dwellings with threshold levels of near 2 mG values where cut off, leaving a cohort of 7 units.

Outdoor EMF:	***"off"/mG***		***"on"/mG***		***"as is"/mG***	
>> 2mG	**ctr**	**corner**	**ctr**	**corner**	**ctr**	**corner**
	3.17	**3.81**	**3.96**	**7.89**	**3.24**	**4.41**
7 units	*51*	*204*	*51*	*204*	*51*	*204*

In the above cohorts, only 1 case exhibits *net current*. It is remarkable that both the "as is" and the "all power on" room centre figures are about double their all-house baseline EMF counterparts (243% and 182%, respectively).

Elevated ambient outdoor EMF levels are not only attributable to electrical distribution or transmission system. With them can be associated multi-ground system effects which can be magnified with indoor and/or outdoor net current dynamics. In such a situation, a greater load indoors can result in a greater imbalance field from the service drop and hence magnification of its magnetic field plus greater effects from the water main and even other grounding wires in the outdoor perimeter of the dwelling unit.

5.13 Electric fields

Electrical fields are about twice higher at the corners than at the room centre. Since outdoor electrical fields are usually below 1 Volt/metre, except at hot spots (Watt meters, etc.), it can be stated that these fields are almost totally created by indoor EMF dynamics. The fields in the corners may be directly attributed to appliances and the wiring and switches. Details about electric fields surveyed are discussed in the case studies.

Electric Fields: "as is" state, indoors	**Centre of rooms** Volt/metre / *sample*	**Corners** Volt/metre / *sample*
41 units	**5.78** / *312*	**10.98** / *1231*

Electric Fields: outdoors	**Corners of structure** Volt/metre / *sample*	**Corners of lot** Volt/metre / *sample*
35 units	**5.74** / *136*	**3.55** / *123*

5.14 The CHMC houses

4 units were presented by CMHC as candidates for surveying across Canada. Their EMF are very low, comparing well with the "low EMF" cases described in 5.11.

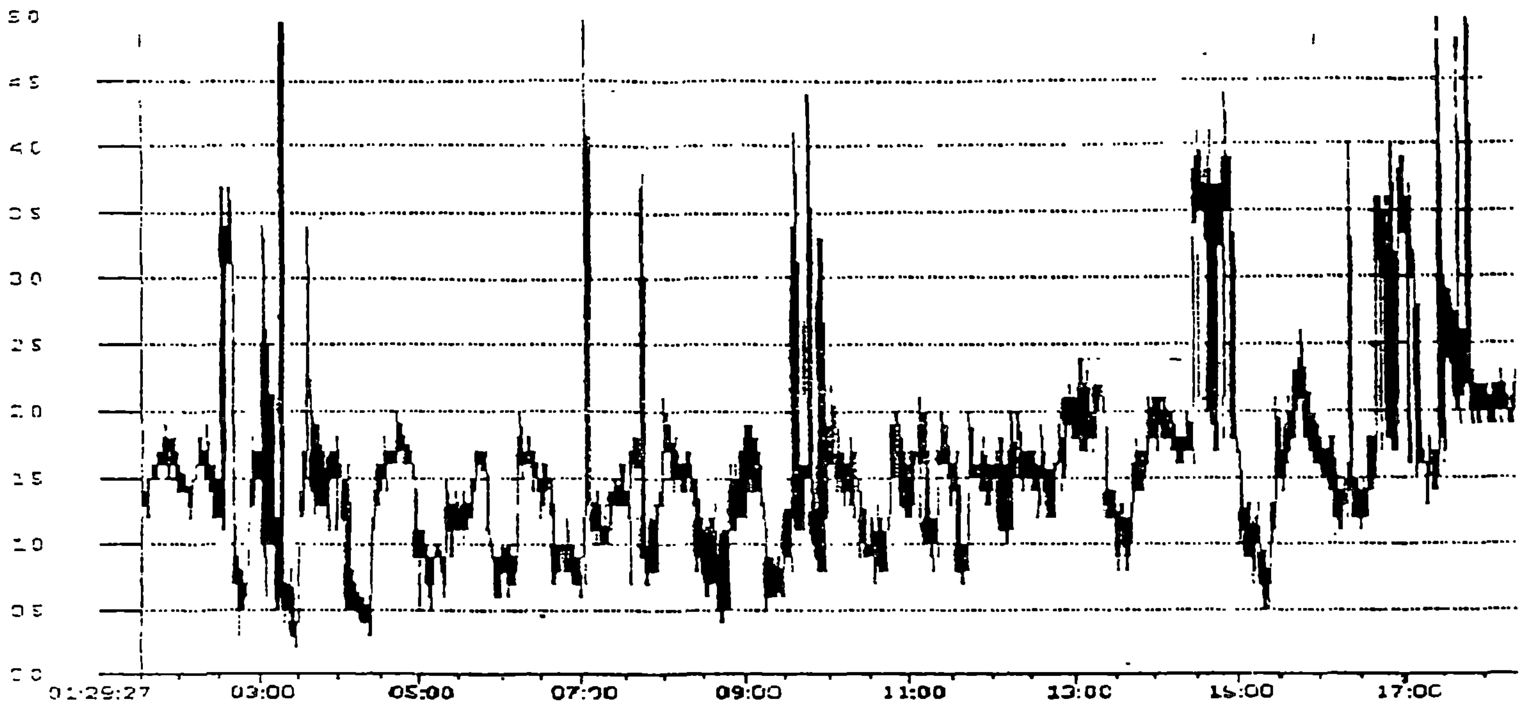
CMHC Houses	***"off"/mG***		***"on"/mG***		**"as is"/*mG***	
	ctr	**corner**	**ctr**	**corner**	**ctr**	**corner**
	0.40	**0.39**	**0.56**	**2.30**	**0.44**	**0.86**
4 units	*32*	*128*	*32*	*128*	*32*	*128*

5.15 Transients

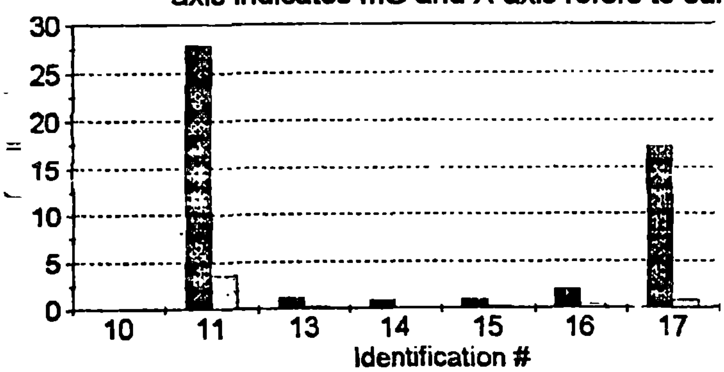
Drs. **Nancy Wertheimer, David A. Savitz** and **Ed Leeper** have found that in houses where ground currents are present, residents are up to four times more likely to contract leukemia. This realization has even caught the attention of the **EPRI** "1,000 home survey" researchers **L. E. Zaffanella** and **Gary B. Johnson** who have articulated why wire codes – which may ultimately be linked to the variability in circuit unbalance in transmission and distribution lines – are more strongly associated with disease risk than are measured magnetic fields. This concern is also shared by **McGill University** Prof. **Paul Héroux** and his colleagues.

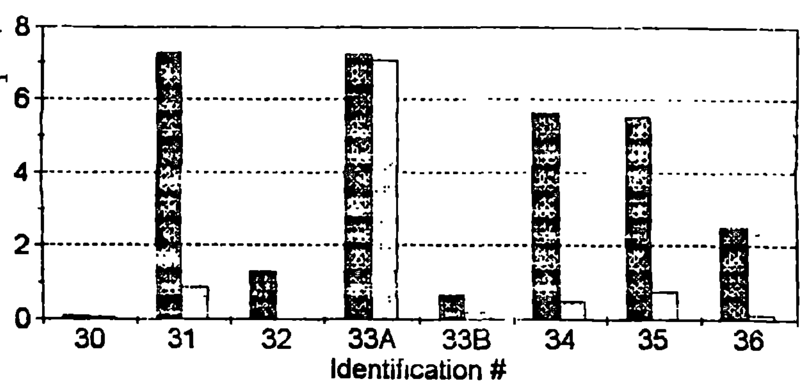
A 1992 project for the **United States Department of Energy** by **Jeff Guttman** *et al.* undertook to determine if there are differences in the number and type of transients in residential environments. No such differences were determined but the team noted that transients were related more to household appliances but showed no evident pattern.

Typical tracing of transient phenomena associated with a grounding to water pipe, in milliGauss, showing minima at about 0.5 mG, average 15 minute fluctuations rising to 2.5 - 3.0 mG and over 30 spikes occurring over an 8 hour period, some peaking at near 4 mG. 6 spikes peak to about 5 mG. This sample is actually a low net current case. Tracing is courtesy of **Ian MacKay of Manitoba Hydro.**



Some *net current* transients noted in survey. Bar graph peak values of currents in the grounding wire can range from between 2X to 5X over period of about 30 minutes. Y-axis indicates mG and X-axis refers to survey cases, with their maxima and minimums.



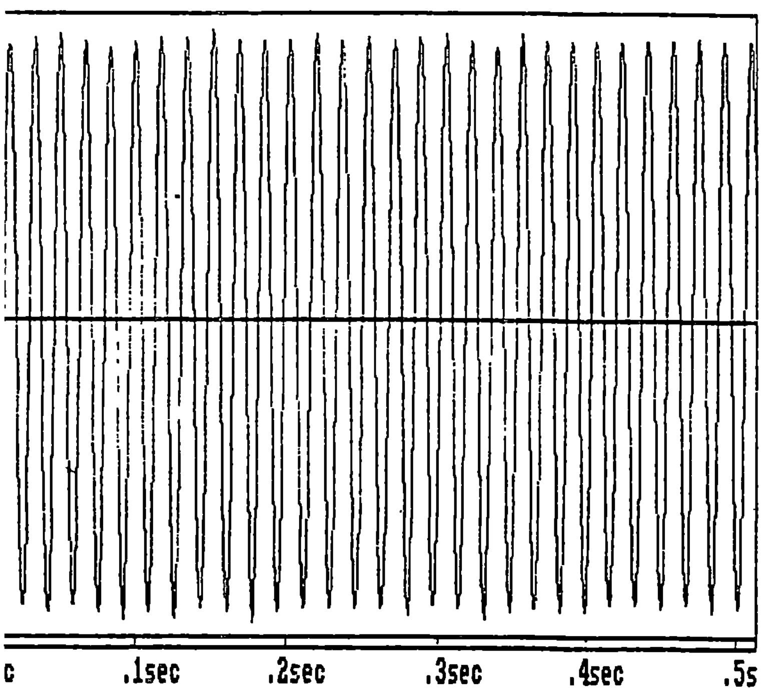


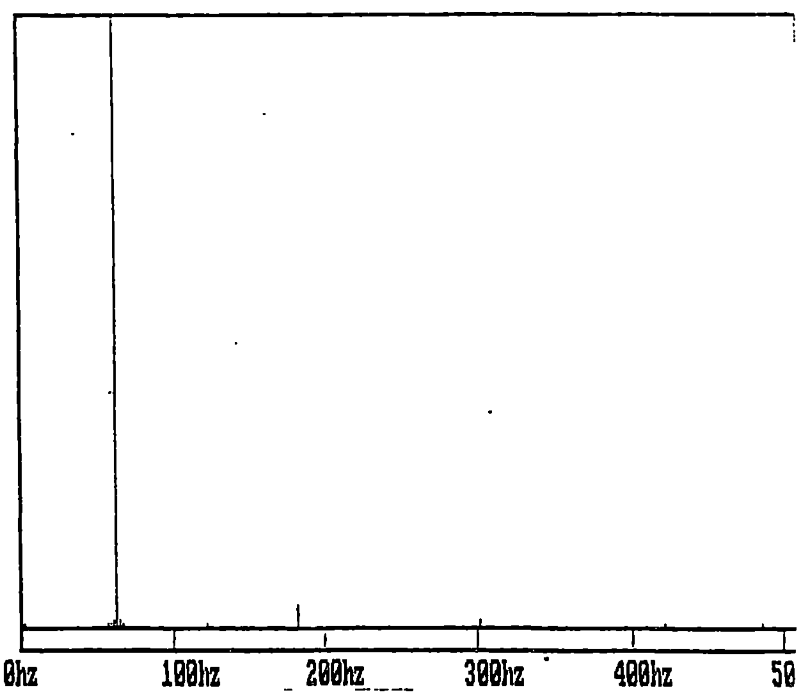
5.16 Spectrum analysis 0 - 25 Hz, 0- 500 Hz range

ELF Spectrum analyses were conducted in rooms and for appliances. Changes occur to the base 60 Hz power frequency, laying the case for a more thorough analysis of indoor EMFs to include 0 - 1000 Hz magnetic flux density measurements.

Dr. **Alan W. Preece of the British Oncology Centre at University of Bristol**, recently pointed out that harmonic measurements can serve to determine interface with two types of hypothesized biological interactions in occupants of dwellings: a) ion resonance + magnetic moments and, b) induced currents. Such data was taken in a 50 home U. K. survey from among 13,895 pregnant mothers funded by the **U.S. Department of Energy**.

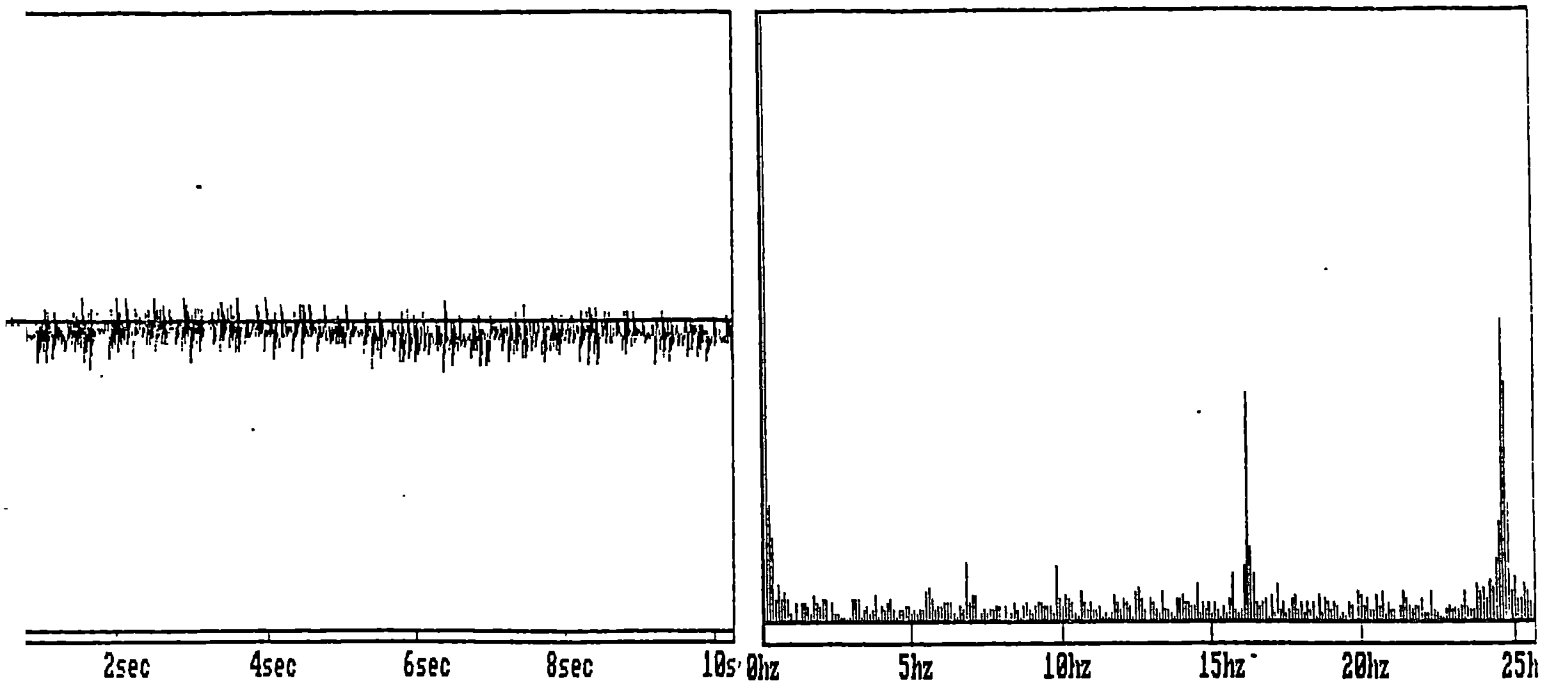
The 60 Hz field is monitored as a clear signal, as shown in the figures below that describe both magnetic field in a 0.5 second time domain and in the (0 - 500 Hz) frequency domain. There are slight irregularities next to the 60 Hz signal and minimal harmonics at 180 Hz.





5.16a Rooms

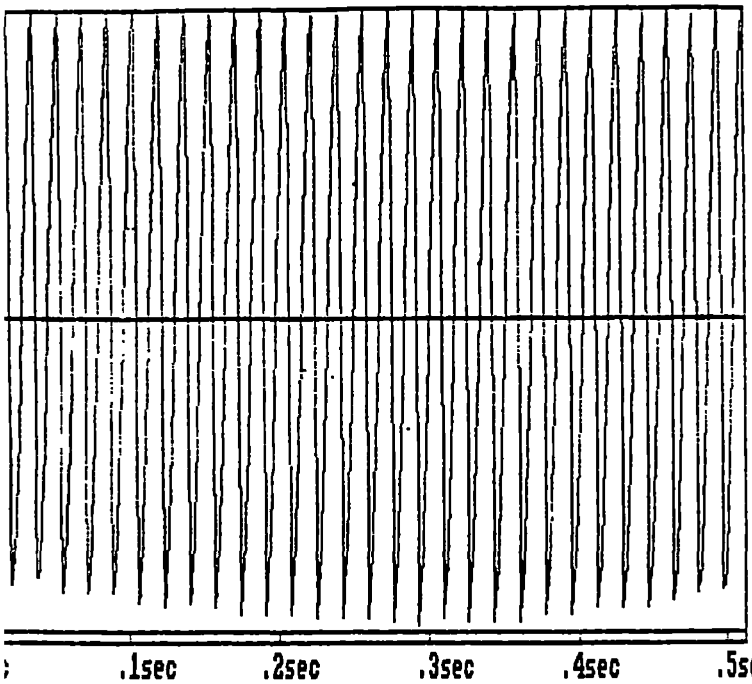
There can exist irregularities in some indoor environments, as shown below which shows only the 0 Hz to the 25 Hz spectrum. The peaks are near 16 and 25 Hz

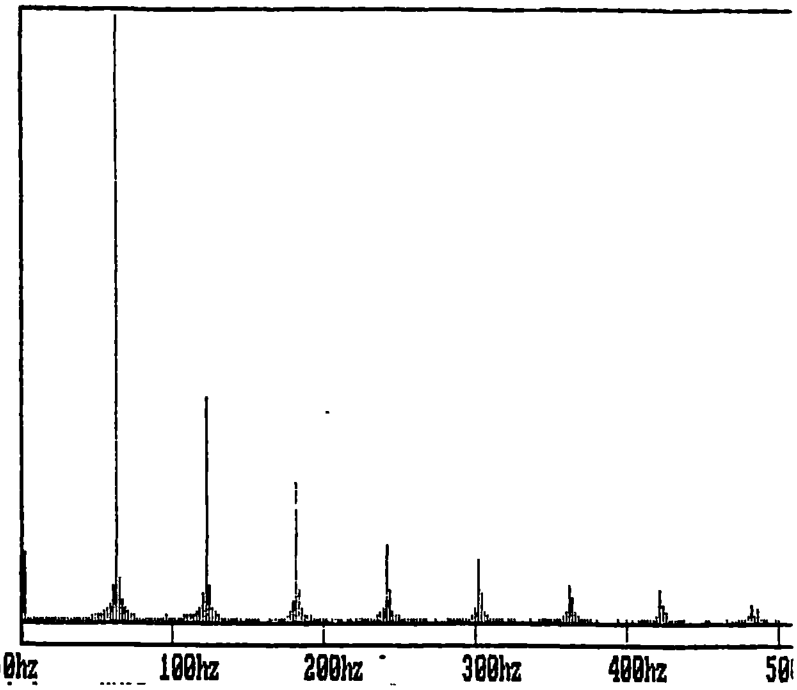


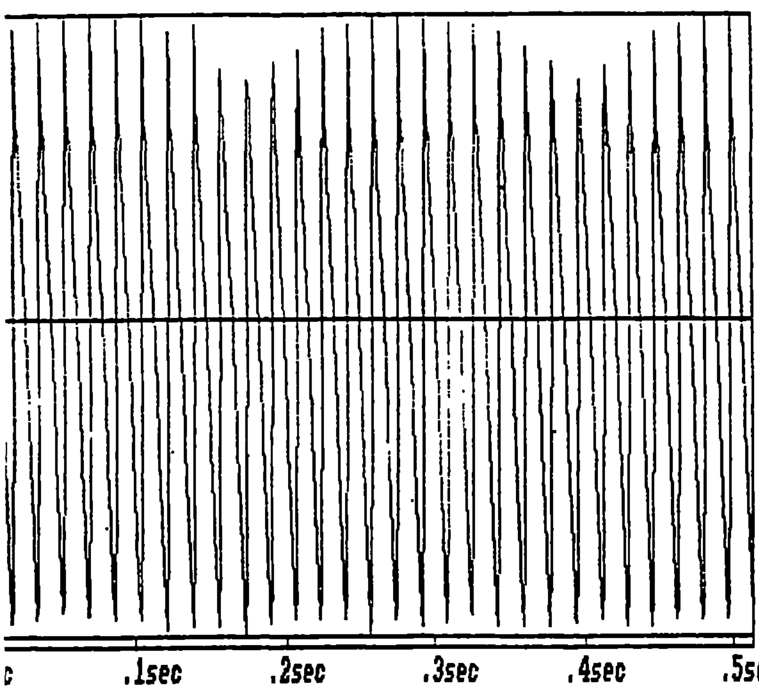
5.16b Appliances and fixtures

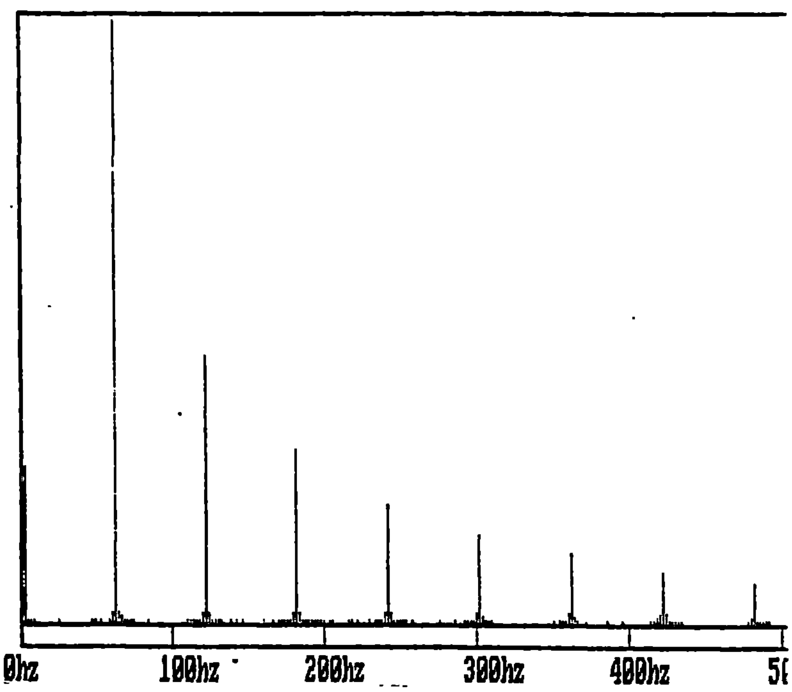
Many appliances produce harmonics.

Video display terminals and TV sets produce a series of harmonics which extend well beyond the 500 Hz – into the 400 kHz. The primary ranges monitored by EMF researchers in Sweden with regards to body absorption characteristics go from 5 Hz to 2 kHz and from 2 kHz to 400 kHz. Below are the two sets of time domain (0.5 second) and frequency analyses done for a Video Display Terminal (at a distance of 20 centimeters) and a TV set (at a distance of 50 centimeters, for the horizontal vector) respectively.

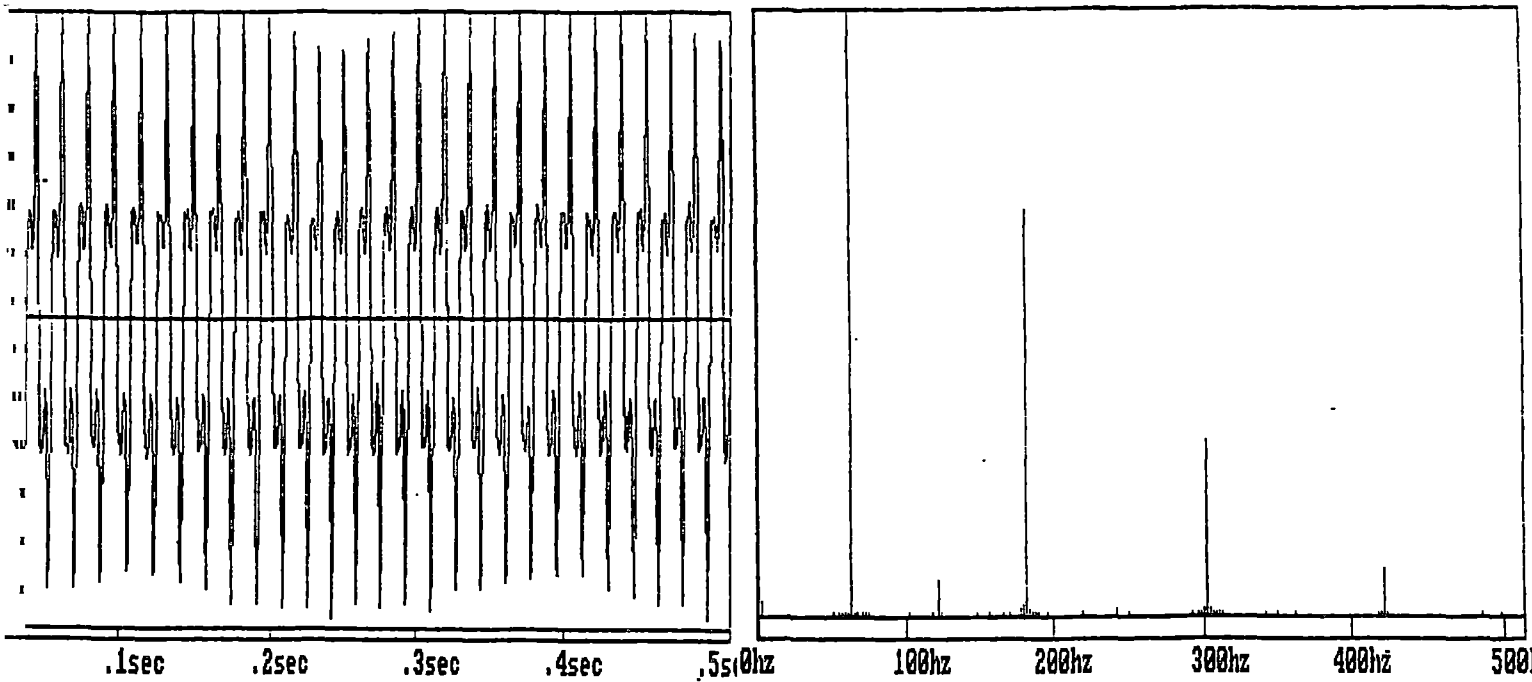

.1sec
.2sec
.3sec
.4sec


0hz
100hz
200hz
300hz
400hz

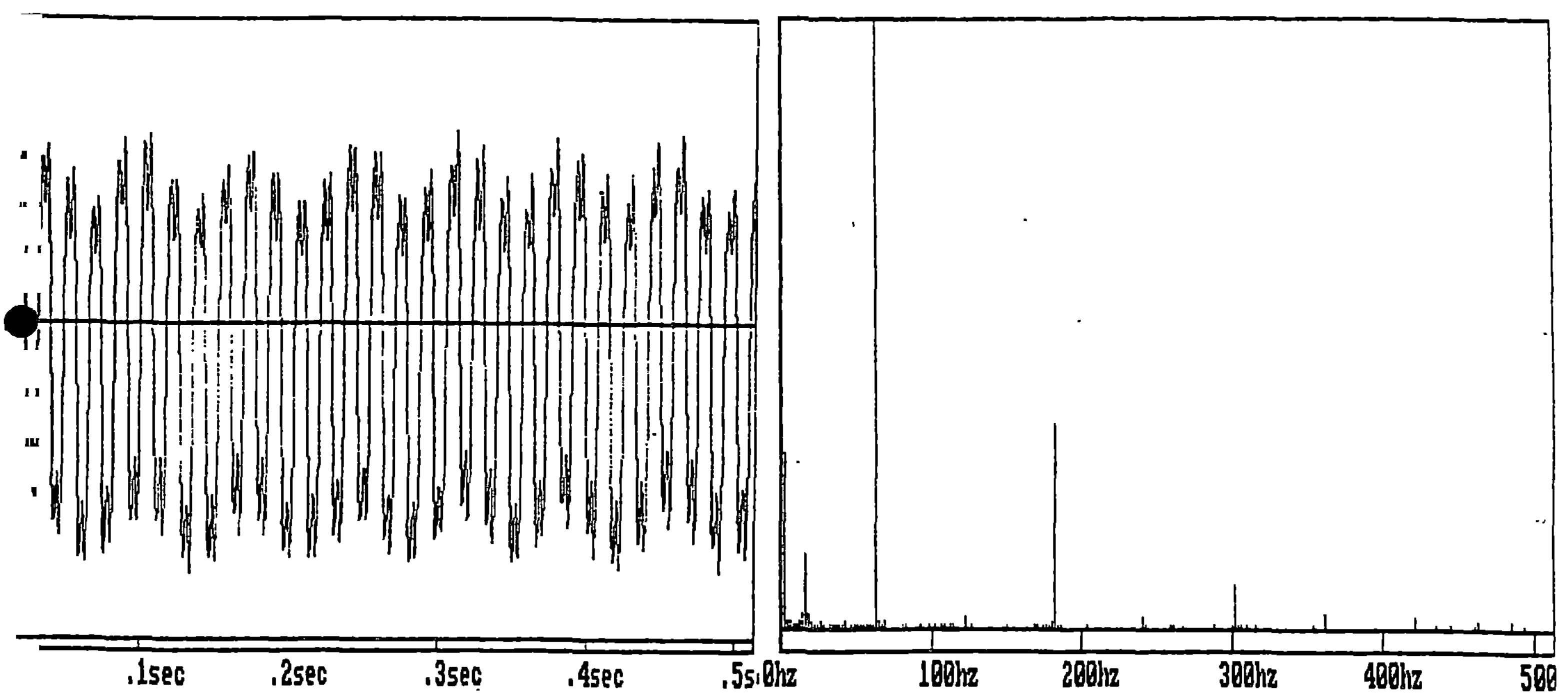

.1sec
.2sec
.3sec
.4sec


0hz
100hz
200hz
300hz
400hz

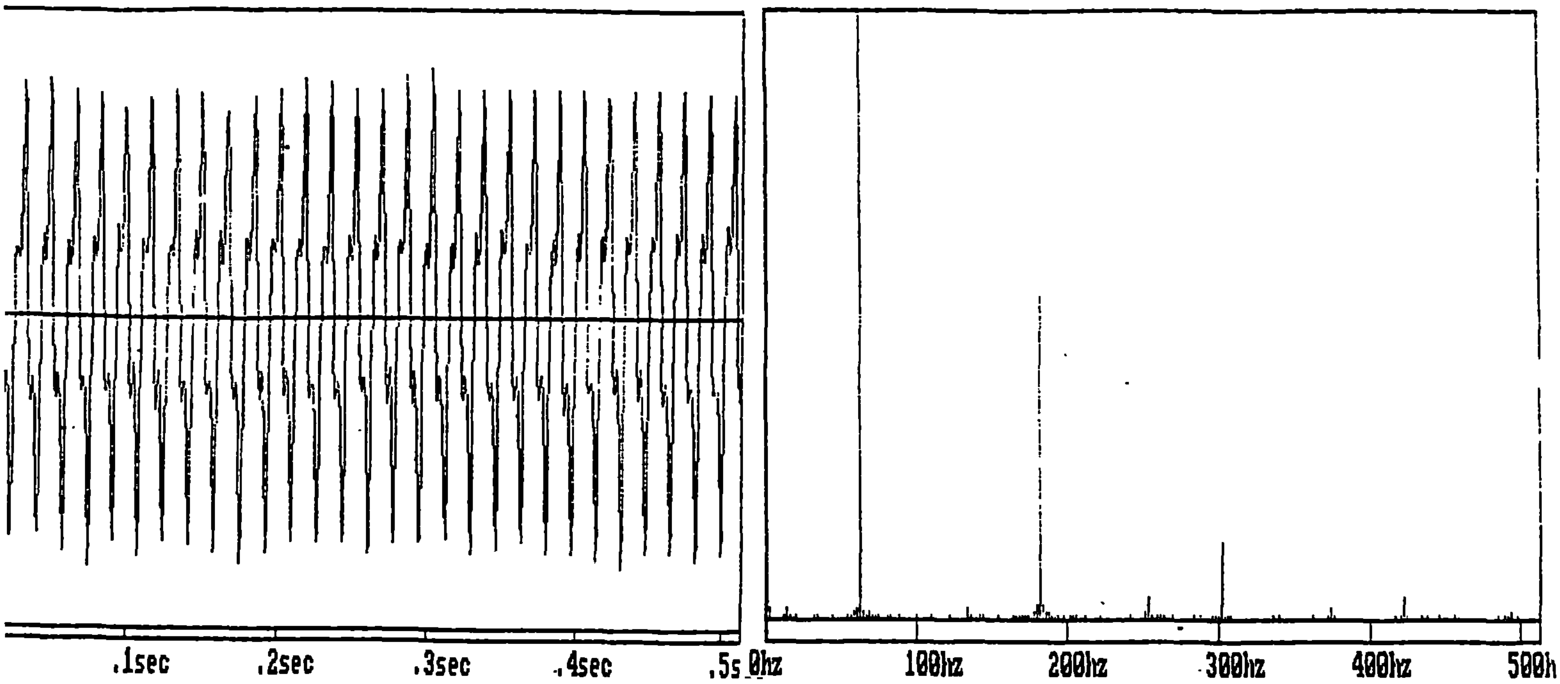
Fluorescent lamp fixtures can produce a highly spiked sawtooth like waveform and alternate, odd number harmonics (3rd, 5th, 7th, etc..) The figures below show a half-second time domain, followed by 0 Hz to 500 Hz frequency analysis.



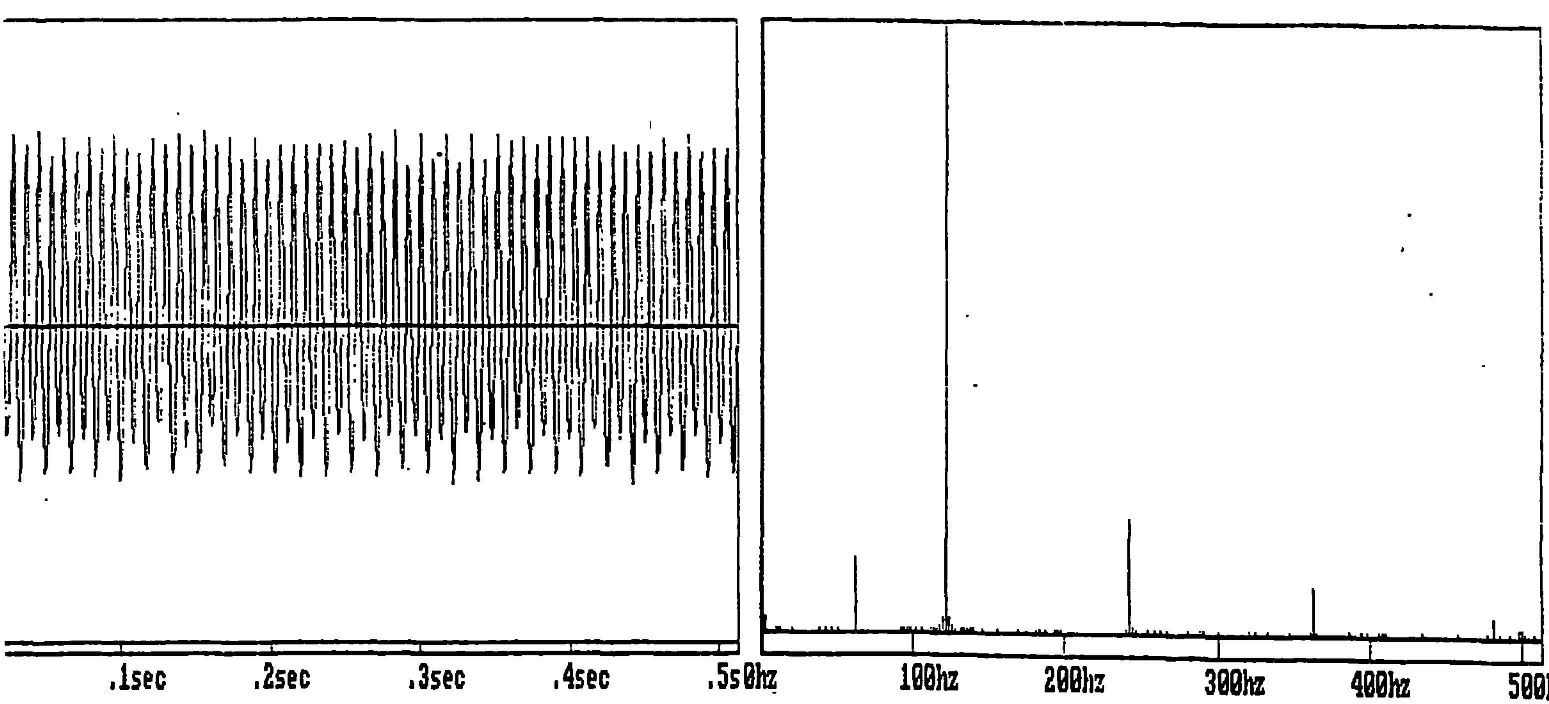
Refrigerators generate a regularly oscillating saw-tooth waveform with the same odd number harmonics disposition as the fluorescent lamps, as shown below.



Some smaller kitchen appliances, like a **coffee grinder** also generate a odd number harmonic disposition, as shown below.



Some devices, such as this **popcorn machine**, can produce a magnetic field harmonic (here the second, 120 Hz) which is much more intense than the 60 Hz component, in this case almost 6X.



5.17 Radiofrequency and microwave

Measurements of radiofrequency and microwave power intensity were undertaken outdoors in all locations. There were no radiofrequency or microwave transmitting facilities within sight, although some occupants did express concern about such identified sources as maritime navigational aides beacons, cellular tower, microwave relay, radar and radio facilities. The highest power density level monitored never exceeded 0.01 milliWattcm^2, well below any known biological significant threshold.

20 dwellings had microwave ovens and each were tested according to the Canadian standard for microwave electromagnetic field requirement: the field strength at 5 cm from the oven surface with a test load of 275 ml of water should be 1 mWcm^2. 4 ovens (20%) had microwave power strength higher than the federal standard, of which three were purchase less than 1 year before. Another 5 units (25%) had field strengths above 0.25 mWcm^2, well above the 0.1 mWcm^2 standards of Poland, Czechoslovakia and the C.I.S. which are based on experimental evidence. 11 microwave units were found to be producing fields below the East European standards level. It should be noted that the same name brand and models were able to emit both the minimal (0.04 mWcm^2) and the maximum field strengths as it appears the radiation characteristics may depend on assembly line factors and wear and tear relative to oven door fixtures. In one "low EMF house" instance, the microwave oven was the only major electromagnetic field problem extant.

5.18 Impact of soil electrical resistivity on *net current*

The amount of current for each component of the total return current leaving a housing unit (neutral, water main, grounding rod, telephone ground, TV cable ground, etc.)

depends on: a) the impedance of the electrical circuit and, b) the relationship between the components. Ultimately, the amount of ground return current dissipating through the soil depends on the resistivity of the soil. This resistivity is measured in ohm-metre.

The soil type (and density) – gravel, sand/gravel, sand, sandy silt, silt, silty clay and clay – also determine the sensitivity of the ground to resistivity to moisture content and the soil temperature.

The electric resistivity of the soil throughout Canada generally decreases during the spring thaw and is apparently the result of differences in the ground temperature and/or the water table which is about 1 meter shallower in the spring than in the winter season. In the summer season, there may be a thin, dry surface layer followed by a more conductive layer and then a resistive layer deeper. In the fall, the surface layer resistivity tends to decrease indicating wetter soil conditions. In the winter season, the frozen surface layer develops greater resistivity.

Resistivity changes very gradually, over days and weeks, so changing both a) the total return ground current leaving the building and b) the load share among the grounding conductors. Most of the ground current travels to the soil nearby; indoors we have the distribution effects through the grounding wires when *net current* is present.

Ground current in the soil seeks the easiest path(s). Because of changing impedance values of ground circuits, the proportion of return current dispersion among the various return components cited above will vary with each change of resistivity. An hypothetical example may explain the dynamics involved: In a single unit house, the return current may be separated in the following way in a particular soil resistivity condition:

Neutral wire:	**70%**
Grounding rod:	**15%**
Water main:	**8%**
TV cable:	**5%**
Phone cable:	**2%**

In this example, we can assume a gradual change in the soil resistivity that induces a 5% increment of current dispersion through the grounding rod -- from 15 % to say 20%. During the same time frame, a similar increment occurs at the water main.

The implication to housing EMF is that the neutral wire -- which plays such an important role in the cancellation effect of magnetic fields at the service drop, and ultimately in the neighbourhood environment -- now has reduced its cancellation effect. The water main's rate of magnetic field dissipation is 1/R. Now the house undergoes a marked increase in magnetic fields -- from the water main, the ground wire to the water main and the ground wire to the ground rods. There is also a greater magnetic field effect from the neutral wire of the service drop because of a greater imbalance of current between the neutral and the hot supply wire.

In such ways, throughout the year, the typical Canadian residence is subject to fluctuations of ground current. The return current tends to be shared among several carrier conductors -- and as the soil resistivity varies, the proportionate relationship between these grounding modes alters the indoor EMF fields. The degree of indoor EMF variability depends on the placement and layout of the conductors involved. In an extreme case, if the grounding wire stretches across the housing unit between the panel and the water main, the relevance of these fluctuations will be heightened through the indoor core. Likewise, if the service drop stretches along a wall or across a roof, the impact on indoor EMF levels next to the path of the electrical supply cable gains importance with such conditions.

In Canada, water pipes and grounding rods are laid below the frost level. For homes with a *net current* problem, as soil resistivity dramatically accrues with colder or frozen soil, ground current is somewhat impeded from exiting via the soil. Return current finds it easier instead to use the utility's neutral. This helps to reduce indoor EMFs.

The soil electrical resistivity factor, however, must be put in perspective. Changes in loading and in the energy consumption generally play a much more significant role in the indoor EMF levels. Keeping all return current components, by reducing *net current*, to a minimum – or nullity is in the interest of homeowners when it comes to prudent avoidance of EMF.

Especially when the primary and secondary distribution lines share the same grounding, they do not require water mains as return paths or optimal grounding with ground rods. Homeowners can still comply with the ***Electrical Code*** and act to shift net current problems from the indoors to outdoors.

Ironically however, from the electrical utility's perspective it is more convenient to have a grounding network with as many grounds as possible – the multi-ground system. Yet, the multi-ground system tends to create an imbalance. Hence, this may result in the reduction in self-cancellation effects of the magnetic fields along the neutral of the service drop for housing units, as well as magnetic field pollution next to each ground wire in the house. Consumers may be subject to higher magnetic fields than it is technically feasible to achieve in the electrical supply to consumers.

The presence of *net current* accelerates the decay of metallic pipes, and poses a concern to the water utility industry. In the United States, the **External Corrosion Committee** for the **American Water Works Association**, led by **R. E. Behnke**, has noted that 1 Amp of current can cause the loss of approximately 20 pounds of metal per year to a pipeline. Water distribution personnel risk electrical shocks when manipulating water meters. Of particular concern is the increasing presence of the DC electric component current traveling through the pipes – which comes from the application of more solid state electronic systems and diodes – found in TV's, dimmer light switches, smart electronic systems, dusk to dawn lights, hair dryers, microwaves, large electric fans, power tools and numerous other applications that apply this type of modification to current wave when they are operational.

5.19 Variation in static magnetic fields

The influence of the static (non varying over time – and also known as DC) magnetic field variances on living systems has been known since ancient times. Currently, some research in this area is directed to the objective detection and analysis of geomagnetic disturbances for geological surveys and has enabled prospecting of mineral, fossil fuel and water resources.

A 1987 environmental health criteria report released by the **World Health Organisation** (WHO) with the **United Nations Environmental Program** (UNEP) noted that, "only a few mechanisms of the interaction of biological tissue with magnetic fields have been established," and that, "other mechanisms may play a role but these have yet to be confirmed experimentally." Nevertheless, the report recognized interactions between variations of static magnetic fields extrapolated to man to include: a) induction of electrical potentials and magnetohydrodynamic effects in the circulatory system; and 2) the direct stimulation of nerve and muscle cells even under extremely weak thresholds. This suggests, it would seem, that even in cases of relatively low contrasts, exposure to a static magnetic field variation might induce, with long-term repetitiveness, a chronic irritating effect.

In some central European nations, considerable experience has been documented on the range of geomagnetic conditions in dwellings and the correlated observable effects on their inhabitants. The essential factor in housing-related measurement and assessments appears to be the percentage of variance of the static magnetic field over the horizontal plane in sites where inhabitants habitually remain for long duration -- such as bedsites. During sleep, which is generally motionless, specific parts of the body tend to be exposed to the same magnetic zone cyclically, often for years, thereby potentially inducing chronic effects.

An important scientific discovery by Dr. **Carl Blackman** indicates a synergistic effect between static magnetic fields, including geomagnetic disturbances and the extremely low frequencies. For example, the identification of a specific ELF frequency to induce critical effects in brain tissue, such as calcium efflux, normally occurs at near 15 Hz. But if the net geomagnetic field is twice as strong, the same effect can be shifted to occur at near 30 Hz. It becomes clear that research or analysis related to electromagnetic conditions should not ignore local static magnetic field conditions. Dr. **Joseph Bowman** of the **United States National Institute for Occupational Safety and Health** confirmed prior research by a colleague, Dr. Peters that when the earth's static magnetic field is analyzed in conjunction with the man-made 60 Hz field, the risk factor of childhood leukemia from home exposure increased from 2 1/2 times to 6 times, and in some cases, even up to 9 times.

Based on observations conducted in Germany and in France by medical scientists, a classifications has been developed to define degrees of hazard to health as per the table below. A safe variation is one in which there is a gradient of not more than 2,000 nanoTesla/meter.

Gradients of the static magnetic field by their level of disturbance in nanoTesla/metre (nT/m).

Normal	*less than*		**2,000**
Threshold	**2,001**	*to*	**3,000**
Disturbed	**3,001**	*to*	**5,000**
Strongly disturbed	**5,001**	*to*	**10,000**
Highly Disturbed	**10,001**	*or more*	

To simplify the analysis in this study, the gradient of static magnetic field disturbance has been rated by a percentage value of the background intensity. In this sense, the following table describes the nomenclature applied in describing the cases reported.

Gradients of the static magnetic field by their level of disturbance in percentage.

Normal	*less than*		**4%**
Threshold	**5%**		
Disturbed	**6 %**	*to*	**9%**
Strongly disturbed	**10 %**	*to*	**14%**
Highly Disturbed	**15%**	*or more*	

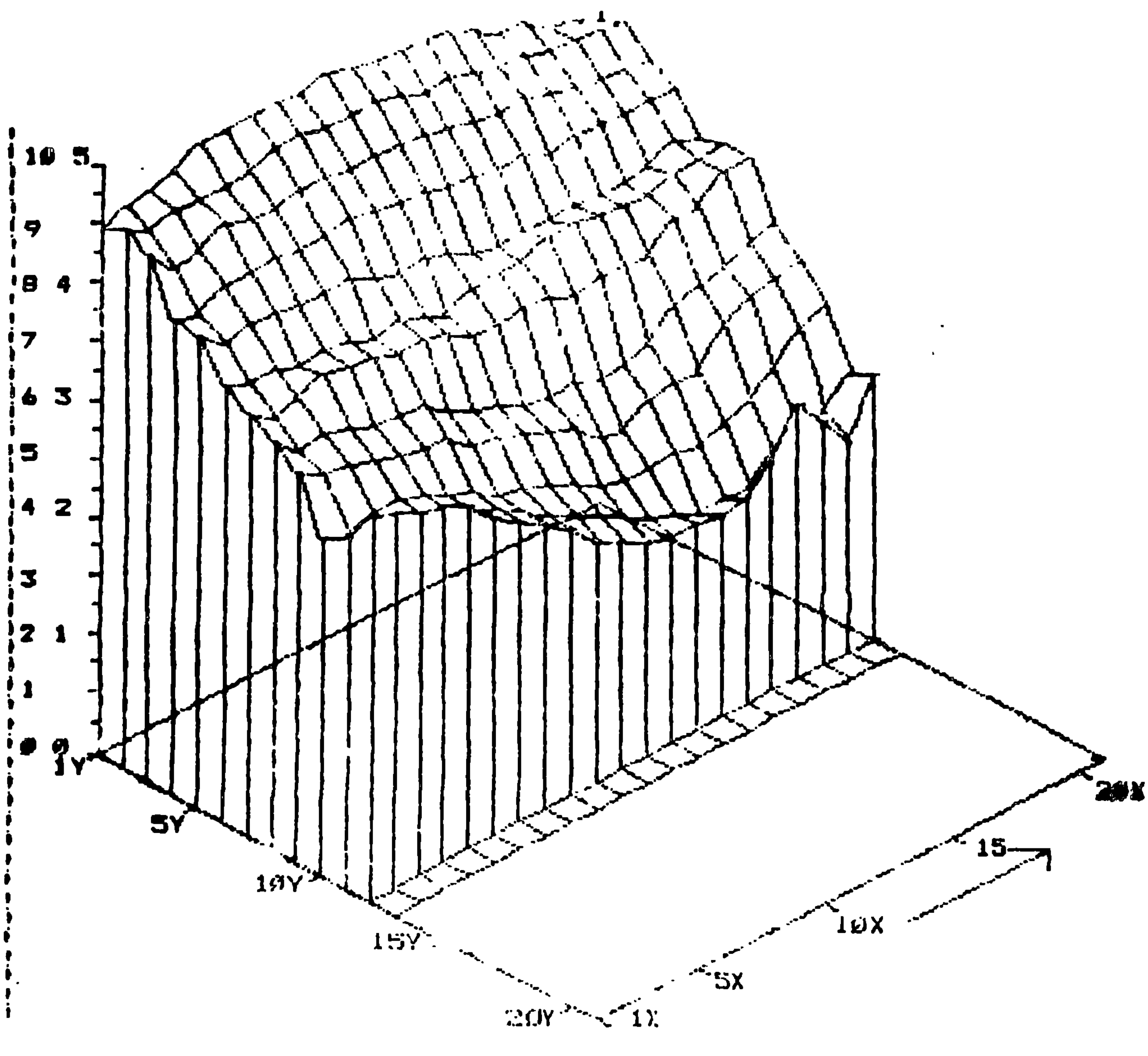
89 site measurements of static magnetic fields were conducted in 37 dwellings, involving 52 long-term use sites.

Of the 52 case studies -- in the large majority involving bedsites -- 30 were determined to be "normal" or "threshold", 7 were "disturbed", 3 were "strongly disturbed" and 2 were "highly disturbed". The cause of disturbance was determined by further on-the-spot analysis and confirmatory measurements.

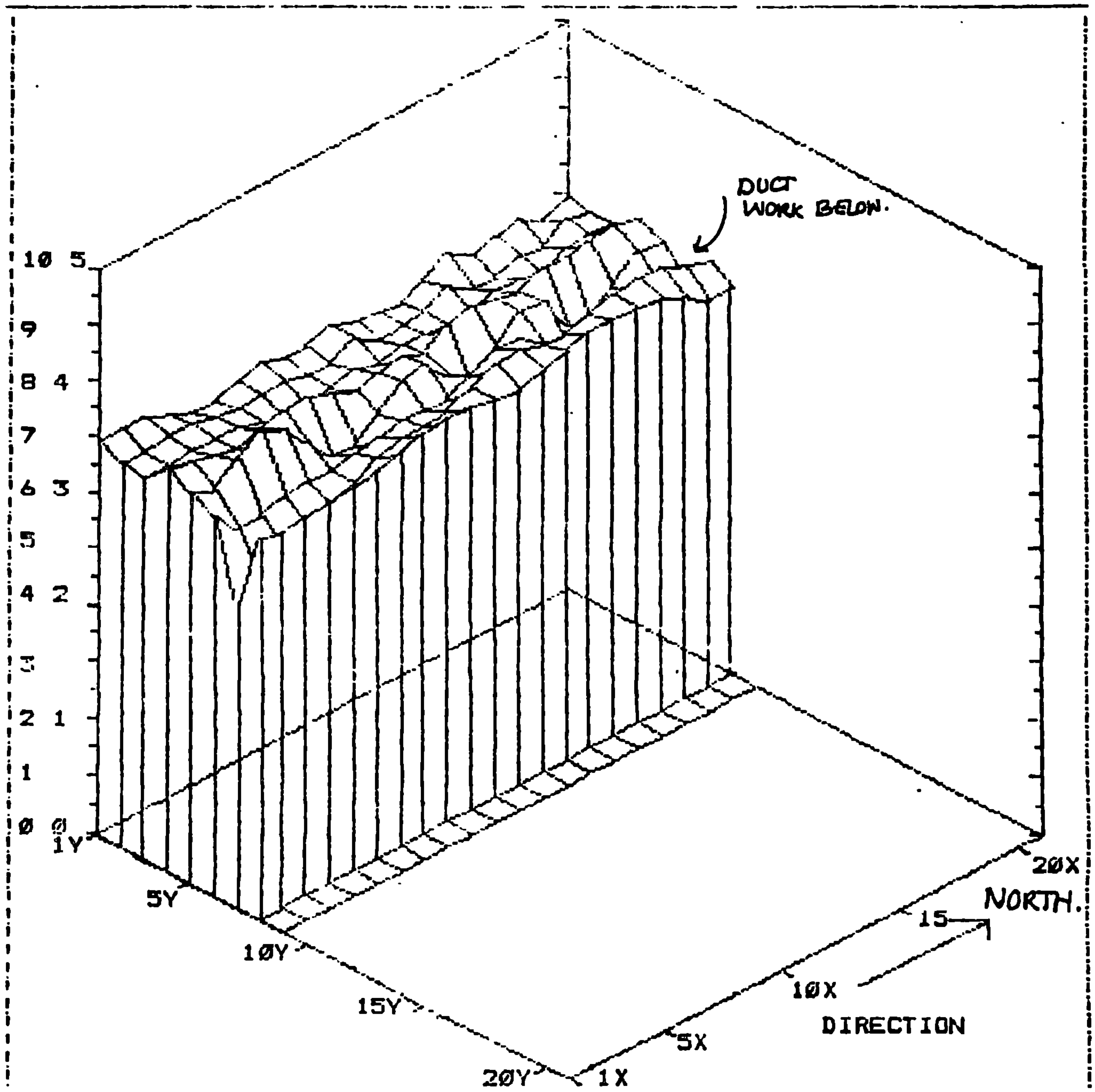
In all the cases surveyed, metallic artifacts were responsible for sharp variances. Beds placed above kitchen appliances, above hardware equipped garages, next to steel structures tend to reflect the consequent magnetic field deviation. Some beds can become magnetically polarized. The presence of a *net current* in metallic conductors can also be reflected in the variances.

Three dimensional graphics illustrations showing these cases are shown below:

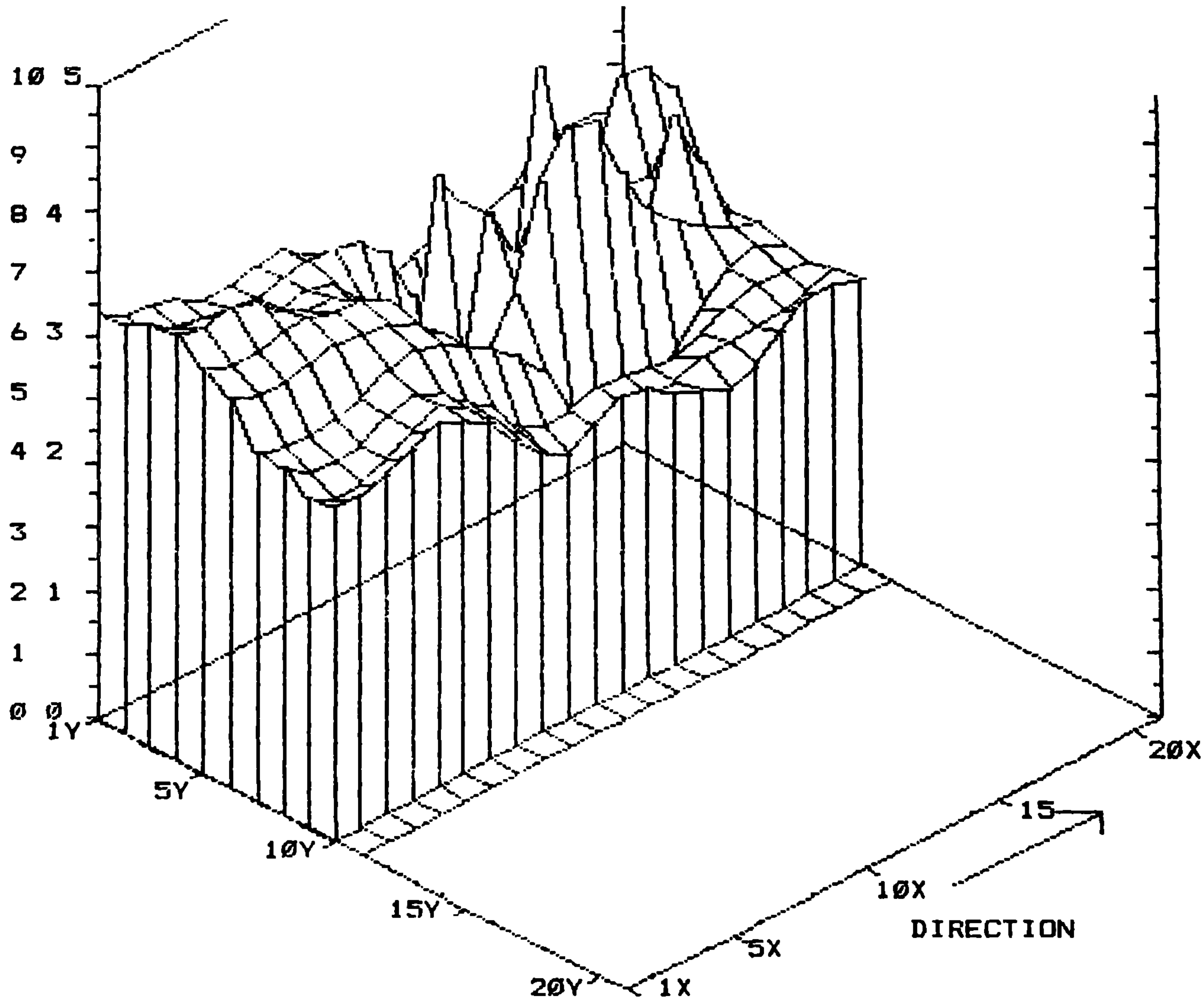
Magnetically polarized bed



Net current in ductwork below.



Presence of metallic artifacts in storey below reflected in bedsite.



Recent environmental field surveys conducted for the EMF RAPID program by **Dr. Luciano Zaffanella** and **C. Hooper** with **Enertech Consultants** in hospitall, schools, office buildings, machine shops, grocery stores and light industry have incorporated spot measurements of the static magnetic field for all rooms (centre of room, and the 4 corners) with the view of establishing a "DC/AC combination." It is possible that this type of measurement will become incorporated more ferquently in EMF housing characterizations in the future once its meaning will become better understood within the EMF research community.

5.20 The "low EMF" dwellings

10 single houses were evaluated to be "low EMF" dwellings. No specific magnetic field level serves as a cut-off for this improvised category, but generally it is implied that fields are often much lower than 0.50 mG and that maximum fields are not above 1 mG. The principal purpose of the discussion about this sample is to delineate those characteristics which can lead to lower EMFs in a dwelling. Two units are not mentioned since the fields have been decreased as a result of mitigation procedures.

Case # 8 – a CMHC "research house" – *frequent field in rooms: 0.01 - 0.08 mG*

The magnetic fields in this house are almost the same whether measured during the "all power *off*" or "all power *on*" conditions. Aside the emphasis for power conservation and quality air exchange/circulation design, the panel is located away from all lived-in zones. The low EMF appliances are the only contributors of EMF, contributing to a maximum residual field of 0.51 mG. The current through the grounding wire is almost 0.0 Amps.

Case # 19 – *frequent field in rooms: 0.05 - 0.40 mG*

This is a very large house, with the main panel installed in the garage, away from any lived-in space. Dimmers and the charging vacuum facility, fish tank and a ventilation system all were sources of elevated EMFs which however, again, did not affect zones of longer-term use. In the "all power *on*" condition, there is a 22.15 Amps current in the grounding wire which, because of the unusually low density, did not affect the fields in the rooms. This case is an example where low density and a suitable panel location mask otherwise undesirable EMFs.

Case # 22 – *frequent field in rooms: 0.04 - 0.12 mG*

This is a compact war-time house in the suburban context with average electrical consumption and aging wiring. The "hot spots" include knob-and-tube wiring installations throughout the house (1.2 to 5.0 mG in sections of walls or flooring) along with the few appliances such as computers and aging electrical oven. However, almost all of the return current goes, as it should, through the neutral. All the ground currents are minimal.

Case # 26 – a CMHC demonstration site – *frequent field in rooms: 0.75 - 1.00 mG*

This low density dwelling designed for mobility impaired users is subject to some outdoor EMFs (around 1.75 mG). The residual magnetic field values for both the "as is" and the "all power *on*" condition are similar. A key feature in this residence is a communications and automatic switching command centre located in the living room which has fields ranging from 3.7 to 5.2 mG sourced to electronic gear. All "hot spots" are appliance-related and the most critical is the electrically heated water bed that provides about 4 mG throughout the bed surface. The outdoor distribution power lines fields and the domestic appliances are the main contributors to elevating fields above 0.75 mG. All the water pipes are nonconductive and heating throughout the premise is provided through the floors by plastic pipes. The main panel is located in the garage, and the grounding wire to the ground rods carries 1.12 Amps is adjacent, hence not providing any magnetic fields.

Case # 27 – *frequent field in rooms: 0.08 - 0.30 mG*

This is a large log house located in a quiet wooded valley. The "all power *on*" state barely increases the residual magnetic fields in the rooms, although some domestic appliances produce elevated fields (laundry machines, refrigerator and old model TVs ranging from 5.32 to 30.4 mG). There is a minimal influence of ground current and the main panel - grounding wire/grounding rods disposition is away from all lived-in areas. The house is serviced by a well. The water pipes and sewage are in plastic. Electric fields are unexpectedly higher than expected (10 - 50 v/m) probably because the wiring system's power frequency serves as a carrier wave for smart devices.

Case # 28 – a CMHC demonstration site – *frequent field in rooms: 0.04 - 0.08 mG*

This is a low density "smart", user-friendly house is designed for the mobility impaired. It has a sophisticated "node zero" installation that interfaces all outside with indoor services. For example, the telephone may be used to switch heating, lighting, etc., and the outdoor cameras feed into the TV sets. The indoor EMFs remain low during both "all power *off*" and "all power *on*" states. Appliances and fluorescent lamps are the main and only sources of localized EMFs ranging from 2.68 up to 23.00 mG. The main panel is in the garage and the grounding wire to Watthourmeter (a regional practice) carries up 3.44 Amps but the localized nature of the system, away from the lived-in zones has no EMF impact on lived-in areas. Indoor pipes are non-conductive and the water main is isolated from the house. The dwelling does have elevated electrical fields (up to 100 V/m) associated with the smart switches which use the power frequency as a carrier along the electrical wires and diodes within the switches.

Case # 31 – a CMHC healthy house – *frequent field in rooms: 0.05 - 0.50 mG*

This is a urban in-fill demonstration design which stresses energy efficiency and which is fortunately located in a low outdoor EMF environment (0.10 - 0.20 mG range) despite the very close presence of a heavy consumption electrical power distribution line. The indoor EMFs increase only marginally even in the "all power *on*" state, because of appliances. The main panel is located in the garage and the grounding wire (which carries up to 7.27 Amps current) exits almost immediately to adjacent grounding rods. The principal "hot spots" are the sophisticated furnace complex which radiates between 3 to 5 mG, a dryer and the refrigerator (14.8 mG).

Two additional multiple units cases, located in favourable EMF wiring contexts inside a large apartment building also had low EMF. However, because it was not possible to obtain proper *net current* details for the building involved, these cases are not being elaborated upon.

6. CASE STUDIES IN MAGNETIC FIELD REDUCTION

Case # 24, 24A, 24B

Case # 24 is a suburban location of medium density, single structure built of wood and serviced by overhead distribution systems. The 75 square meter 2-story house with basement was renovated in 1979s from a 1948 built shell structure.

This dwelling was the object of 5 mitigation exercises. The first measurements indicated abnormally elevated field as compared to very low magnetic fields elsewhere in the single unit house, and in the surrounding outdoors – usually less that 0.20 mG.

The first mitigation involved greater care in a tidier redirection of wires in parallel in the basement below (to allow greater cancellation effects and to minimize some current loop effects) and in the proper grounding of various supply pipes. This resulted in halving the magnetic field in zones directly above the basement wiring. The kitchen readings decreased from 6.00 - 7.60 mG reduced to readings ranging from 1.00 to 2.80 mG, and in the living room they fell from 0.24 to about 0.08 mG.

The second mitigation involved the installation of a dielectric coupler – a six inch schedule 80 PVC nipple – in the main water pipe, with proper adjustments for grounding via ground rods. The third mitigation involved tracing 2 return current loops (about 0.5 Amps) and the fixing of a three-way switch in which 1 wire was shorting. The current loop found to go between the water pipe, the water heater, gas pipe, furnace, ventilation ducts and the grounded pipe of the electrical supply. The second was traced between the grounding wire to the water furnace, the ventilation duct and the grounding pipe of the electrical supply. The solution involved insulation of the ventilation duct from the grounded pipe of the electrical supply. These initiatives further decreased the kitchen fields from 1.00 to 2.80 mG to about 0.04 to 0.68 mG -- or about 5% pre-mitigation values.

However, an anomaly was noted, namely that when the "all power *off*" state was measured in some spots of the kitchen, the field was lower than with "all power *on*" or in the "as is" state. A sample same corner reading was: "all power off": 0.68 mG, "all power *on*": 0.56 mG and "as is" 0.08. This suggested the presence of a minor *net current* (up to 0.60 A in *on* position) coming from outside of the house through shielded TV cable (which is now the only contact with the multi-ground distribution system). Nevertheless, this prompted a search for still other *net currents*. Therefore, the fourth mitigation involved the identification of a low intensity current loop between the water pipe, the water heater, the gas supply pipe. The mitigation involves the installation of a dielectric coupler in the gas pipe feeding the water heater.

The fifth mitigation exercise involved the magnetic polarization of a metal-frame bed as a result of previous prolonged exposure to high EMFs. The frame was replaced.

The costs of the mitigation were:

1) installation of the dielectric coupler in water main and rewiring.
2) insertion of piece of wood,
3) installation of dielectric coupler in gas supply pipe to water heater.

Value obtained for mitigation: Considerably less magnetic field throughout residence -- up to 20X reduction.

Case # 18

Case # 18 is a rural location of low density, single structure built of wood and serviced by overhead distribution systems and using water drawn from a well on the lot. The 135 square meter single story house with basement was built in 1990.

Two mitigations were conducted. The magnetic fields indoors ranged from about 0.10 to about 0.50 mG except in the kitchen/dining/office rooms zone adjacent to an "imperfect" panel box configuration located below in the basement. This area, covering about one third of the large house had fields ranging from about 0.85 to 2.00 mG. However, considerable transient, harmonics and general oscillation the magnetic fields were monitored. Transients were noted to rise from 0.10 to about 6.0 and up to 25 mG, inside the house and to a lesser extent outdoors near the power service drop.

The first mitigation involved the re-furbishing of a ground wire leading to the lightning arrestors and the pole transformer on the closest distribution pole -- which had been severed, probably during a lawn mowing. It did provide critical protection against lightning for the entire neighbourhood. It also provided an improved maintenance of potential difference between the neutral and the hot wires of the distribution line. It seemed to reduce some of the larger transient activity, although the rationale for this observation is not understood.

The second mitigation dealt with improvements to the panel. The panel had 2 neutral bars joined together by a metal strip. 2 ground bars were joined to the neutral by a panel screw. 2 ground wires a) for the grounding rods and b) to water pipes were bonded to the 2 neutral bars separately. Both ground wires went together outside through the same panel entrance tied by a screw. The result of this configuration was a parallel current loop for the return neutral current of up to 7 Amps from the first neutral bar to the second neutral bar through two parts of ground wires inside the panel. The mitigation consisted of putting together both grounding wires on the same side of the neutral bar.

The costs of the mitigation were:

1) rewiring
2) labour time and ground rod (the work should have been done better by the utility which should have provided at least 2 rods, considering the isolation of the area and proximity to a mountain that could attract electrical storms)

Value obtained for mitigation: Lightning protection to an isolated neighbourhood Considerably less magnetic field throughout the affected zone by up to 5X reduction and elimination of current heating process between the ground wires at the bad connection – a potential fire hazard.

Case # 21

Case # 21 is an urban, high density, multiple, wood construction co-operative housing structure serviced by an overhead distribution system. The 140 square meter 3-story town-house type unit without basement was built in 1981.

Originally, the 3rd floor master bedroom faced at eyelevel a 75 kVA transformer servicing a 12 kV 3-phase distribution line about 3 metres away. The horizontal proximity of an unshielded triplex service drop contributed during the evening hours an average magnetic field of 6.3 mG throughout the bedroom with 30 mG measured at the bed pillow.

The local utility undertook a mitigation exercise involving compaction of 3 distribution system wires, current balancing and improvements in contact points between conductors and the pole-mounted 3 transformers adjacent to bedroom. All this was done without moving any utility fixture or changing the distance to the bedroom.

The mitigation reduced the average bedroom field from 6.3 mG to 0.68. Maximum measured in the room was 0.92 mG at the corner closest to the transformer. In the outdoor part of the wall closest to the pole mounted triple set of transformers, the highest measured field was 2.75 mG, while the outdoor wall and window itself had fields ranging from 1.17 mG to about 2.25 mG over a lateral profile of about 3.5 metres.

The compaction mitigation exercise reduced fields generally by 10X and by almost 30X at the most critical site -- the head position of the occupant in the long-term exposure, sleeping state.

The costs of the mitigation were:

1) research and design by the utility

2) compaction and rewiring by the utility

Value obtained for mitigation: remarkable procedure which can be provided as routine magnetic field reduction method with immediate application for relief to entire neighbourhoods in numerous distribution situation. Such compaction procedure would provide the principal relief in 2 other high priority cases encountered during the survey -- where it would also reduce fields indoor at least 10 fold – Cases # 10 and # 20. It could also provide significant relief of about 3 to 5X for about two more.

Cross house *net current* mitigation - Case # 33A, 33 B

This is a suburban, low-density, single wood 85 sqm house being renovated over a 1950 shell with the view of optimizing energy efficiency and conservation. During the initial survey, *net current* related magnetic fields were generally often in the 5 to 15 mG range, with a maximum reading of 54.6 mG. There was an elevated current going through the 10 metre long grounding wire – up to 7.71 Amps. This wire extended along the mid basement ceiling between the panel box on one end of the house to the water main installation on the other extremity. To this bare wire were bonded all the ground wires from all appliances. All the water and sewage pipes were in plastic.

The mitigation involved disconnecting the principal grounding wire from the water main. Two ground rods were installed immediately outside the panel and these were bonded according to the ***Electrical Code***.

The costs of the mitigation were:

1) installation of two ground rods and new connections to the main panel.

Value obtained for mitigation: Considerably less magnetic field throughout the affected zone by up to 5X reduction and about 50 X in the worst zone. The neutral carried greater load, reducing the ambiental EMF affecting the rear service drop of the house by 15% (from 5.15 down to 4.40) and 45 % from 1.1 to 0.6 mG near the water main. Meanwhile, the neighbouring fields (during the peak suppertime) had risen from nearly 2 to 10 X (for example from 0.15 to 1.10, 0.2 to 2.00, 0.75 to 1.40, 0.5 to 1.8mG).

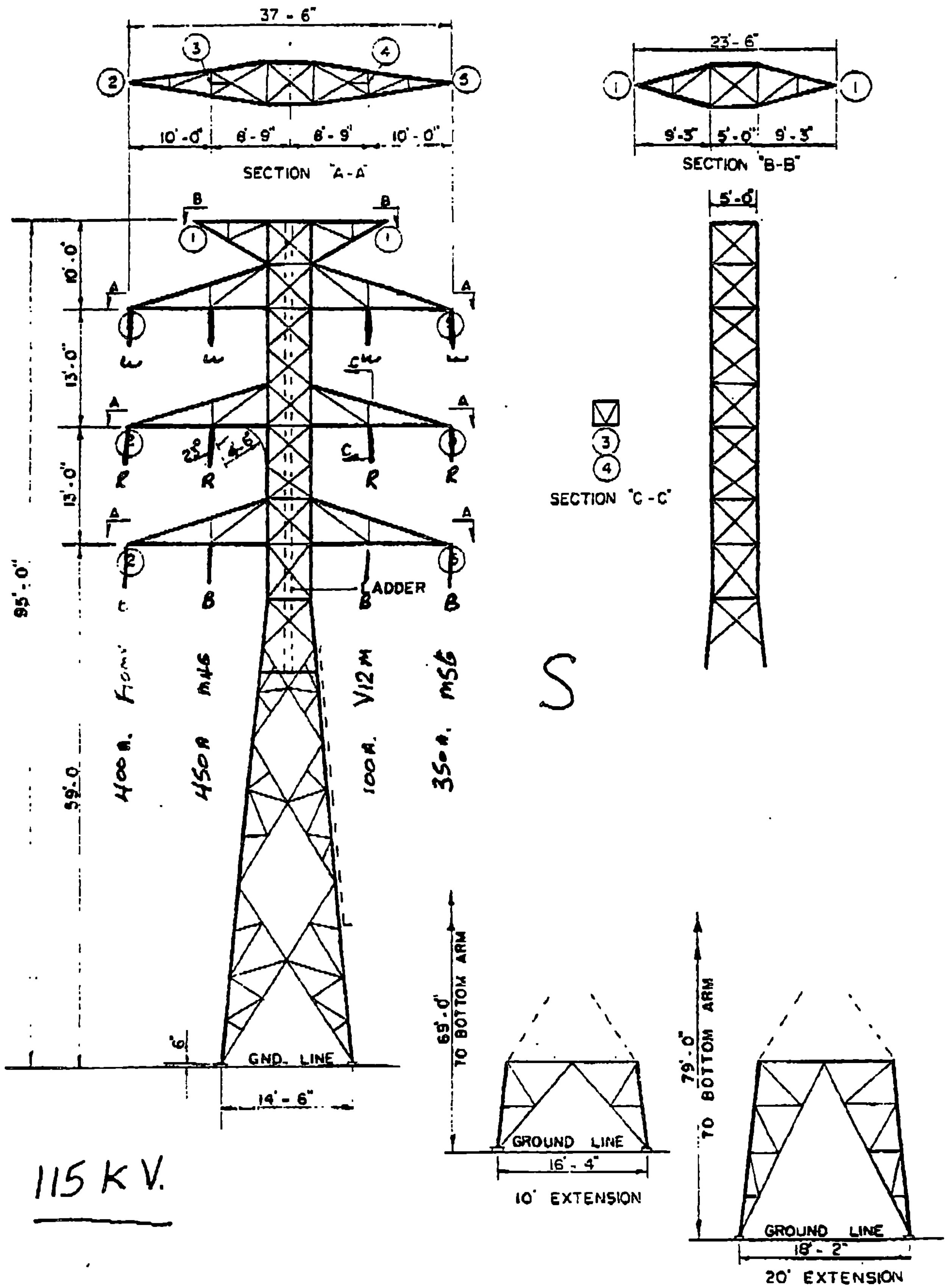
Nota bene: The mitigation specifications were misunderstood by the electrician. He had disconnected the main ground wire from the panel, which had to be re-connected.

Transmission line mitigation (Case # 15)

A 115 kilovolt 4 circuit Type H3S transmission line produces 25 mG at the right of way, impacting structures bordering it. The same magnetic field characteristics were modeled based on technical specifications provided by **Ontario Hydro.** After computer trials, a reconfiguration – reversed phase – was modeled to provide at least 3 X times less field.

The costs of the mitigation are:

1) design and computer time;
2) labour by the utility and maybe additional insulators in substation during the changing of the reversed phase positions (no cost/minimum cost).



115 kV
FOUR CIRCUIT
TYPE H3S
SUSPENSION TOWER

APPROVED .... R G Wykes .... APRIL 15, 1966
T. & D. DESIGN ENGINEER

Current 14 conductor system **with 12 energized phases configuration with modelled magnetic fields in Gauss.**

Phase Code	Horiz. Dist (m)	Vert Dist (m)	Bundle	Diam (mm)	Vph-G	Ph-Shift (Degrees)	Iph (kA)
PH w1	**-5.71**	**24.44**	**1**	**33.980**	**66.400**	**-120.000**	**.400**
PH.r1	**-5.71**	**20.40**	**1**	**33.980**	**66.400**	**.000**	**.400**
PH b1	**-5.71**	**16.47**	**1**	**33.980**	**66.400**	**120.000**	**.400**
PH.w2	**-2.66**	**24.44**	**1**	**33.980**	**66.400**	**-120.000**	**.450**
PH.r2	**-2.66**	**20.40**	**1**	**33.980**	**66.400**	**.000**	**.450**
PH.b2	**-2.66**	**16.47**	**1**	**33.980**	**66.400**	**120.000**	**.450**
PH w3	**2.66**	**24.44**	**1**	**33.980**	**66.400**	**-120.000**	**.100**
PH.r3	**2.66**	**20.40**	**1**	**33.980**	**66.400**	**.000**	**.100**
PH.b3	**2.66**	**16.47**	**1**	**33.980**	**66.400**	**120.000**	**.100**
PH w4	**5.71**	**24.44**	**1**	**33.980**	**66.400**	**-120.000**	**.350**
PH.r4	**5.71**	**20.40**	**1**	**33.980**	**66.400**	**.000**	**.350**
PH.b4	**5.71**	**16.47**	**1**	**33.980**	**66.400**	**120.000**	**.350**
GND1	**-3.07**	**28.75**	**1**	**13.550**	**.000**	**.000**	**.000**
GND2	**3.07**	**28.75**	**1**	**13.550**	**.000**	**.000**	**.000**

SENSOR HT = 1 0 MTRS

DIST FROM REFERENCE (m)	*CURRENT CONFIGURATION* **B-FIELD (GAUSS)**
-30 0	**.01490565**
-27 0	**.01722438**
-24 0	**.01997474**
-21 0	**.02319346**
-18.0	**.02686270**
-15 0	**.03085476**
-12.0	**.03486803**
-9 0	**.03840901**
-6 0	**.04091020**
-3 0	**.04199362**
0	**.04166964**
3 0	**.04022377**
6 0	**.03792014**
9.0	**.03491899**
12.0	**.03142748**
15 0	**.02775402**
18.0	**.02419967**
21 0	**.02096224**
24.0	**.01812620**
27 0	**.01569807**
30 0	**.01364393**

Reversed phase, mitigated configuration **with physical phase description and modelled magnetic fields. Compare effects at - 15 and + 15 metres from axis.**

Phase Code	Horiz. Dist. (m)	Vert. Dist. (m)	Bundle	Diam (mm)	Vph-G	Ph-Shift (Degrees)	Iph (kA)
'PH.b1 '	-5.71	24 44	1	33.980	66 400	120.000	.400
'PH.r1 '	-5.71	20.44	1	33.980	66 400	.000	.400
'PH.w1 '	-5.71	16.47	1	33 980	66.400	-120.000	.400
'PH.w2 '	-2.66	24.44	1	33 980	66.400	-120.000	450
'PH.r2 '	-2.66	20 40	1	33.980	66.400	.000	.450
'PH.b2 '	-2.66	16.47	1	33.980	66.400	120.000	.450
'PH.b3 '	2 66	24.44	1	33.980	66 400	120.000	.100
'PH r3 '	2.66	20.40	1	33.980	66.400	.000	.100
'PH.w3 '	2.66	16.47	1	33.980	66 400	-120.000	.100
'PH.w4 '	5.71	24.44	1	33.980	66.400	-120.000	.350
'PH r4 '	5.71	20.40	1	33.980	66.400	.000	.350
'PH.b4 '	5.71	16.47	1	33.980	66 400	120.000	.350
'GND1 '	-3.07	28 75	1	13.550	.000	.000	.000
'GND2 '	3.07	28.75	1	13.550	000	.000	.000

SENSOR HT. = 1.0 MTRS

DIST FROM REFERENCE (m)	B-FIELD (GAUSS) Reversed Phases
-30.0	**.00225862**
-27.0	**.00271542**
-24.0	**.00332774**
-21.0	**.00414684**
-18 0	**.00522935**
-15.0	**.00662143**
-12.0	**.00832076**
-9.0	**.01021573**
-6 0	**.01204946**
-3 0	**.01350262**
.0	**.01437212**
3 0	**.01462602**
6.0	**.01428782**
9 0	**.01340026**
12.0	**.01209977**
15 0	**.01060392**
18.0	**.00911377**
21.0	**.00775397**
24 0	**.00657555**
27.0	**.00558324**
30 0	**.00475963**

Geomagnetic mitigation (Case # 25)

The setting is a mobile home with a free standing addition sealed against it, located in the wilderness. In one bedroom, a metallic service fixture is located below a bedsite, producing a 49.9% static magnetic field disturbance, very similar to the one shown on page 84. Due to the compactness of the trailer it was impossible to move either the fixture or the bedsite.

The mitigation involved the placement of two small 3 " square flat dipole printed circuit antennae known as the ***Dar-Zon***, which evened out the disturbance to a more acceptable gradient of less than 4.8% in the most affected area, a 10X improvement.

The costs of the mitigation were:

1) installation of two units for a value of $ 40.

7. END REMARKS

At the start of the field surveys, concern was expressed by reviewers about the original small sample size of 30 which was expanded to 43 surveys – 11 in British Columbia, 8 in the Prairies, 18 in Ontario and 6 in Quebec. These cases now appear to be indicative of the Canadian housing stock: they display a realistic sampling of EMF problem conditions as well as positive situations. This sample probably reflects the range but not necessarily the actual proportion of situations across Canada. Data results reflect the preceding EMF survey experience of independent consultants, and some corroborate published findings by other researchers, suggesting that the sample is sound and unbiased. The database is rich and appears to provide useful indicators and to indicate remedials. The first results are preliminary, pending the expert input and co-operation of reviewers and researchers and the potential integration with results of other studies.

As the project was active, the standards and regulation process concerning the power frequency domain has been accelerating rapidly towards the lower thresholds, lower than many of the magnetic and electric field levels that have been documented during the surveys. This international trend will be or is already impacting on the utilities' technical procedures in Canada. Its momentum will also sink into significance among architects, planners, municipalities, builders and the construction trade supply and service communities (including electricians and plumbers). The building inspection practice may have to accommodate appended new checklists. An "education" process will now have to be developed to enable a more professional and better understanding and application of the Electrical Code so that the emerging lower EMF thresholds can be met in Canadian housing. Canada Mortgage and Housing Corporation's mandate overlaps into such initiatives. Commensurate with such changes will be the increased interest among the general public to approach EMF issues more technically and matter-of-factly.

In this study, the "CMHC houses" came out in good light. Part of the success depends on corporation's drive for energy conservation and efficiency as well as the application of good design practice of attention to important details. Though energy conservation and efficiency are helpful in lowering indoor EMFs, it is still necessary to contend with various potential miswiring pitfalls, choice of appliances and the multi-ground system of the current electric transmission and distribution technology. A simple wiring error for a 300 Watt lamp fixture can inadvertently result in an elevated 6 mG field at a distance of 1 metre from source. Some appliances are enormous EMF polluters. The multi-ground system, unless encountered with expertise, albeit low cost "surgery" or goodwill co-operation with the utilities, can spring surprises indoors even with the best of design intentions.

During the course of this exercise, several bridges were built with the utilities and various municipal and provincial authorities across Canada. There may be hope for creative and effective coping with EMF issues in joint initiatives. It may be possible to: a) implement technical mitigation for both transmission and distribution power lines; b) geographically map and cost mitigation strategies for communities and; c) conduct complex but instructive demonstration indoor EMF remedials, including the issue of *net current* corrosion avoidance for concrete foundations.

This survey exercise has clearly demonstrated that all technically useful, solutions-oriented surveys must be conducted with both the "all power *off*" indoors and the "all power *on*" states. The first situation reveals the EMF characteristics related to the nearby primary transmission and distribution power line, and especially the secondary distribution lines and the associated multi-ground system. The "all power *on*" state highlights all the "hot spots" and reveals miswiring and is most helpful in suggesting mitigation options as well as informing the occupants on how to adopt prudent avoidance strategies. The "as is" state does not represent the true distribution of EMF characteristics in a dwelling.

Each dwelling presents its own special EMF case. There does not exist one EMF formula for all Canadian housing. This leads to the suggestion that all Canadian houses would be properly inspected for EMF prior to occupancy or to change of ownership.

Concerning training builders and electricians, there are a few rules that could be stressed: 1) the location of the main panel is a critical matter. It is, in itself a major "hot spot" and should be positioned away from any lived-in areas; 2) the location of the water main should be next to the main panel, as well as the ground wires of the other incoming services such as the telephone and TV cables. The main grounding wire from the panel should be strung at the shortest wire distance possible to the water main, and not at the ceiling. The grounding rods, when used, should be installed as close to the panel as possible to minimize the grounding wire length and to minimize magnetic fields; 3) Non-conductive pipes should be considered for water and sewage indoors to reduce inadvertent paths of *net current*; 4) EMF can be substantially minimized by the careful layout of ground wires.

The Canadian demand for EMF mitigation is enormous and though this study suggests that the remedial actions are indeed efficacious and very low cost, these require intelligent planning, educational initiatives and policy promotion.

EMFs from appliances play a significant role in housing occupant exposure. Electrical manufacturers should be encouraged to test their products for EMF characteristics prior to merchandising and provide labeling describing such. A good example is the progress achieved in EMF reduction by most manufacturers of video display terminals and electric blankets. The European Union has established an EMF labeling system that assists consumers in assessing appliances according to exposure expectations.

During this study a few other aspects of EMF have emerged:

1) a new electric field source is emerging with smart houses and new electric switch and contact products. These fields are at intensities to which a growing proportion of the population can react to. There also remains an unmapped domain of indoor air ion dynamics related to building materials, construction practices as well as wiring.

2) the examination of static (or DC) magnetic fields has shown that its preferable not to locate bedsites above garages and kitchens;

3) there exist EMF conditions which are so complex and multi-tiered that it was impossible to mitigate these within the time frame of this project. The complexity involves step-by-step resolution of multiple net current circuits, especially in residences that have undergone several electrical renovations and for which a protocol and simplified mitigation procedures must yet be designed. Some cases may involve co-operation by utilities for entire neighbourhoods serviced by a multi-ground system and this too requires time and administration follow-up and follow-through. During this exercise 6 such candidates have emerged (Cases # 4, 7, 7B, 11, 17 and 32). A novel and experimental mitigation technique, called by the **Electrical Power Research Institute** as the NCC (Net current coupler) has been designed recently and it may be

able to provide neighbourhood-wide cancellation effect for EMFs from the multi-ground system. Some joint bridgework with utilities could implemented with the introduction of this technology to Canada.

Recommendations:

It is recommended that, jointly with interested parties:

1) More data be compiled based on the project's database and on its coupling with compatible databases from other research collated under the United States EMF RAPID program and other Canadian studies, as may be suggested by reviewers.

2) More work could be done in refining and evaluating complex indoor EMF mitigation procedures.

3) Outdoor EMF mitigation exercises be conducted and evaluated in conjunction with utilities a) as per the computer modeled mitigation procedure indicated in the report regarding the reversed phases configuration and; b) with the NCC neighbourhood EMF cancellation effect coupler.

4) A process for divulging the technical aspects of EMF as well as the associated mitigation methodologies to the building trades industry be developed and implemented.

5) Special publications be developed to enable the general public to identify and deal with EMFs in Canadian housing.

6) A review and verification of the possible deleterious effects of *net currents* and ground currents on reinforced concrete foundations and describe, test hypothesis with remedial procedures.

APPENDIX I

THE SURVEY QUESTIONNAIRE

Canada Mortgage and Housing Corporation
Planetary Association for Clean Energy
Survey of electromagnetic field levels in Canadian housing

CONFIDENTIAL
when filled out

IDENTIFICATION CODE:

DATE OF SURVEY: ____/____ TIME IN: ___:___ OUT ___:___
month day

SURVEYORS:

TYPE:

setting:	urban	suburban	rural/isolated/wilderness	
density:	high	medium	low	
unit:	multiple	single		
construction:	concrete	stone	wood	metal
utility:	overhead	underground		

UNIT:

address

city province postal code

contact tel # 1 tel # 2

BUILDING LIFE:

when built: latest structural renovations: type:
wiring age: latest electrical renovations: type: partial/total:

other remarks:

UTILITIES:

external:

distance from secondary line: capacity: closest side:

closest mast: approach of feed line:

distance/location transformer: nearest room(s) for power/wires, entry:

distance from HV line & capacity (if applicable):

distance,type,age water main: distance from gas main:

distance/location satellite dish: distance/location/type telecommunication tower(s):

configurations for all feeders: electric, water, gas, cablevision, telephone (on plan)

other remarks:

____

____

____

____

____

internal:

power entry (location; amp): panel location: average daily kwh

subpanel location: avg. daily kWh: subpanel location: avg. daily kWh:

water pipes: lead copper plastic

heating system (fuel, forced air, hydronic, radiant):

cooling system (central, decentralised): Central air purifier:

cablevision: how installed: ______________________________

security type: how installed: ______________________________

remote power switch: fibreoptics (where):

other remarks:

____

____

____

____

____

GROUNDING CHARACTERISTICS:

exit to ground mass distance, configurational approach from power entry:

contact(s) with other conveyors, by type: multiple ground:

other remarks (including soil resistivity):

RESIDENCE SIZE:

sqm floors basement

other remarks

RESIDENCE MATERIALS:

foundation: floor: windows, frame type: coated pane:

doors: siding: chimney: fence: rebar:

other remarks:

APPLIANCES: (0-X)

oven/stove	refrigerator	microwave	freezer	washer/dryer
air purifier	humidifier	TV/VCR	entertainment	clock radio
computer	fax	aquarium	sauna	office equipment
jacuzzi	other			

ASSESSMENT:

external/internal relationships:
(consistency, patterns, attenuation factor)

horizontal/directional relationships:

vertical/directional relationships:

outdoor hot spots:

***check & comment:** (type [including composite], location, density, re-radiation, E or H, E/H conversion)*

powerline: grounding: transformer: entry: telephone:

cable: water main: gas main: water table: meter:

roofing: fencing: radar: telecom: neighbour:

subway, streetcar:

type:

---

type:

---

type:

---

type:

---

type:

---

indoor hot spots:

***check & comment:** (type [including composite], location, intensity, re-radiation, E or H, E/H conversion, identify product, where possible)*

wiring:	walls:	floors:	ducts:	pipes:
windows:	appliances:	lamps:	HVAC:	office equipment:
grounding:	transformer:	dimmer:	alarm clock:	

type:

type:

type:

type:

type:

INDOOR SPOT MAGNETIC / ELECTRIC FIELD READINGS

readings: mG/V/m
o = *oscillating (w/rate)*
h = *harmonics content*

IDENTIFICATION # ______ ROOM ____

USAGE: _______ hours   age _________ years   male/female _______

AS IS:

Centre: / Corners (A,B,C,D) / , / , / , /

ALL POWER "ON"
Centre: / Corners (A,B,C,D) / , / , / , /

ALL POWER "OFF"
Centre: / Corners (A,B,C,D) / , / , / , /

Appliance *in mG*, type:	at 10 cm	at 50 cm
Appliance *in mG*, type:	at 10 cm	at 50 cm
Appliance *in mG*, type:	at 10 cm	at 50 cm
Appliance *in mG*, type:	at 10 cm	at 50 cm
Appliance *in mG*, type:	at 10 cm	at 50 cm
Appliance *in mG*, type:	at 10 cm	at 50 cm
Appliance *in mG*, type:	at 10 cm	at 50 cm
Appliance *in mG*, type:	at 10 cm	at 50 cm

OUTDOOR SPOT MAGNETIC / ELECTRIC FIELD READINGS

readings: mG/V/m
o = *oscillating (w/rate)*
h = *harmonics content*

IDENTIFICATION # ______

Corners lot (A,B,C,D) / , / , / , /

Corners structure (A,B,C,D) / , / , / , /

Power supply, at structure at ______ (d)

Water Supply, at structure at ______ (d)

Gas Supply, at structure at ______ (d)

Other __________________ at ______ (d)

Other __________________ at ______ (d)

Lateral Profile (if applicable) Description: ________________________________

Start point ____________; 1 ____ (d) ; 2 ____ (d) ; 3 ____ (d) ; 4 ____ (d) ; 5 ____ (d)

Lateral Profile (if applicable) Description: ________________________________

Start point ____________; 1 ____ (d) ; 2 ____ (d) ; 3 ____ (d) ; 4 ____ (d) ; 5 ____ (d)

1. Fixture *in mG*, type:	at 10 cm	at 50 cm
2. Fixture *in mG*, type:	at 10 cm	at 50 cm
3. Fixture *in mG*, type:	at 10 cm	at 50 cm
4. Fixture *in mG*, type:	at 10 cm	at 50 cm
5. Fixture *in mG*, type:	at 10 cm	at 50 cm
6. Fixture *in mG*, type:	at 10 cm	at 50 cm
7. Fixture *in mG*, type:	at 10 cm	at 50 cm
8. Fixture *in mG*, type:	at 10 cm	at 50 cm
9. Fixture *in mG*, type:	at 10 cm	at 50 cm
10. Fixture *in mG*, type:	at 10 cm	at 50 cm

RADIO FREQUENCY AND MICROWAVE *(in milliWatt/cm²)*

continuous:	intermittent:	/minute	identified source:
continuous:	intermittent:	/minute	identified source:

24 HOUR READING OF MAGNETIC FIELDS

IDENTIFICATION # ______________

Place	Minimum	Maximum	Average
Place	Minimum	Maximum	Average
Place	Minimum	Maximum	Average
Place	Minimum	Maximum	Average

NEUTRAL AND NET CURRENT READINGS

IDENTIFICATION # __________________

MAIN PANEL:

	MAIN CIRCUIT BREAKER "off"	"on"
Neutral Supply Conductor:	|	
Grounding wire:	|	
Water pipe:	|	
Gas pipe:	|	
Other: _______________	|	

SUB PANEL (Main circuit breaker in "on" position:

Neutral conductor:

Grounding Wire:

SPECTRUM ANALYSIS (1 - 500 Hz) *(optional)*

Harmonics: Peak intensities at: _______ Hz _______ Hz _______ Hz _______ Hz _______ Hz _______ Hz _______ Hz _______ Hz

Highest harmonic: _______ Hz

Oscillations at: _______ Hz

CROSS-SECTION (indoor-outdoor attenuation) *in mG* (where applicable only):

inside wall: outside wall:

at 2.5m indoors: at 2.5 m outdoors

remarks re: (confounding factors: wiring, etc.; electric field. RF/mW, etc.)

____
____
____
____
____
____
____
____

GEOPHYSICAL AND STATIC MAGNETIC FIELD OBSERVATIONS:

IDENTIFICATION # ____________________

STATIC MAGNETIC FIELDS

General range: lower ______________ **average** ______________ **higher** ______________

Compensation _______________ **nanoTesla**

CASE STUDY (when applicable)

Location (room): _________________ (zone) __________________

Disturbance percentage _______ % Identified cause _________________

CASE STUDY (when applicable)

Location (room): _________________ (zone) __________________

Disturbance percentage _______ % Identified cause _________________

CASE STUDY (when applicable)

Location (room): _________________ (zone) __________________

Disturbance percentage _______ % Identified cause _________________

CASE STUDY (when applicable)

Location (room): _________________ (zone) __________________

Disturbance percentage _______ % Identified cause _________________

CASE PROFILE (when applicable)

Location (room): _________________ (zone) __________________

Description ____

Disturbance percentage _______ % Identified cause _________________

Soil resistivity ________________ (estimate yes/no) ____________

contributing factors

____

____

____

APPENDIX II

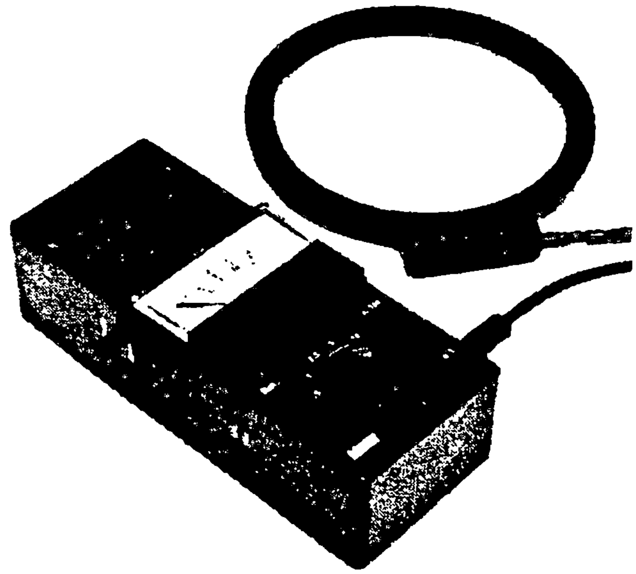
INSTRUMENT SPECIFICATION

Monitor Industries

Exploratory AC Milligaussmeter

Model 42B-1

- Stable Low-level Measurements
- True RMS Reading — Flat Response 40 Hz to 1 kHz
- Audio Monitoring Speaker
- Insensitive to Coil Movement in the Earth's Magnetic Field
- Lightweight — Compact — Convenient Operation



DESCRIPTION:

The 42B-1 Milligaussmeter is an accurate, dependable instrument designed for ease in locating environmental sources of AC magnetic fields, and for accurate measurement of magnetic fields at electric power distribution frequencies, plus overtones.

Field detection is by a lightweight 6 inch coil. The usual sensitivity of such a coil to movement in the earth's DC magnetic field has been virtually eliminated by a sharp low-frequency cut-off below 40 Hz. As a result, even on the lowest scale (.5 milligauss) the coil can be hand held, and rotated to find a maximum field direction, without producing spurious bobbing or pegging of the meter's needle.

An internal speaker provides audio monitoring of the AC fields being measured. Audio output is useful when rotating or moving the coil to maximize a reading. It also gives a qualitative indication of the frequency spectrum being measured. This "overtone signature" can help in differentiating and tracking down various magnetic field sources that may be simultaneously present.

Calibration stability and the insensitivity of the 42B-1 Milligaussmeter to electric field and radio frequency error sources are assured by use of low-impedance circuitry throughout, and by internal shielding of case and coil.

Frequency response is flat over power distribution frequencies and their major overtones, while rejecting higher-frequency "hash". An additional linear mode —i.e. sensitivity proportional to frequency—gives a qualitative indication of overtone content.

SPECIFICATIONS:

Ranges: Twelve scales from .5 milligauss full scale to 2.5 gauss (.5, 1, 2.5, 5, 10, 25 milligauss scales plus a "× 100" jack)

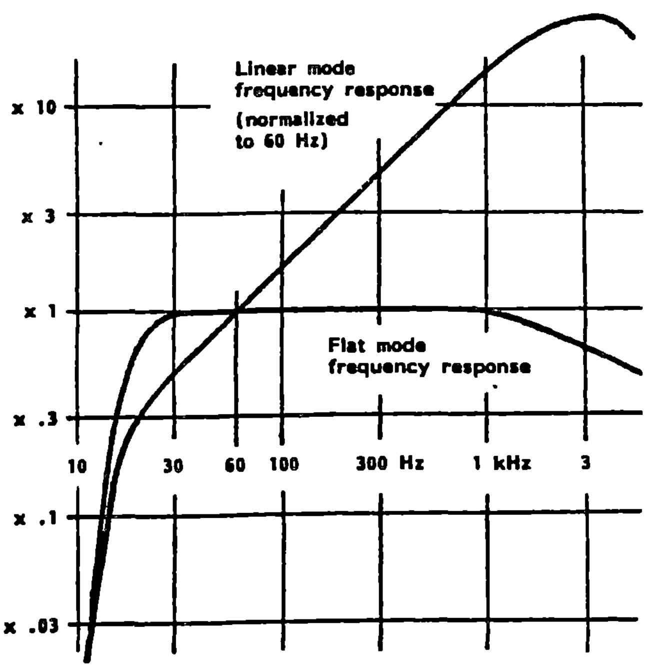
Resolution: .01 milligauss per division on the .5 milligauss scale

Accuracy: ±[5% of reading + one division], 50 Hz to 600 Hz

Response to non-sinusoidal wave forms: True RMS

Noise signal: Less than .01 milligauss (1 milligauss on the × 100 scales)

Frequency response: Flat (i.e. equal meter readings for equal milligauss fields) +2%, -5%, from 40 Hz to 1 kHz; ±2%, 50 Hz to 300 Hz



Frequency response in linear mode: Linear (i.e. meter reading is proportional to frequency for equal milligauss fields) +2%, -5%, 40 Hz to 800 Hz; ±2%, 50 Hz to 300 Hz

Overload protection: 50 gauss continuous; 100 gauss, 1 second surge

Power: Two standard 9V alkaline batteries (included). Battery life is approximately 4 hours of full scale readings with the speaker turned on, 15 hours with speaker off. Low-battery warning light.

On-off switch: Can be used with momentary "push to read" actuation for long battery life, or latching "push on, push off" actuation by depressing the button further

Weight: 1 lb. 14 oz. (850 gm), including batteries and coil

Case dimensions: 2 1/4" x 3 1/4" x 8" (55 x 80 x 200 mm)

Coil diameter: 6 3/4" (170 mm)

Models:	July 1990 prices
42B-1 Milligaussmeter with both flat and linear modes	$525
(Model 42B no longer available)	
Hard shell plastic carrying case	25
Retrofit of linear mode option on a 42B or 42A meter	100

(Prices include ground shipment within the 48 states. If a 42B-1 meter or linear mode retrofit is to be used primarily with a 50 Hz power system, please indicate.)

Monitor Industries

6112 Fourmile Canyon, Boulder, Colorado 80302
303/442-3773

Calibration Check

In spite of the excellent calibration stability of the 42B-1 Milligaussmeter, some users may wish to do a calibration check from time to time —either a precise recalibration for scientific purposes or simply a rough check to be sure there isn't something wrong with the meter when one gets a particularly surprising reading. (Unusually high or low magnetic fields do occur, for a variety of reasons.)

For a precise calibration, a measured 60 Hz (or 50 Hz) current is fed to a large diameter coil, with the 42B-1 meter's detector coil at its center. Details of the suggested procedure are available on request.

To do a periodic rough calibration check, it is suggested that some "standard field source" be located and its field level recorded. This can be any appliance that puts out a fairly pure 60 Hz field strong enough at a distance of two feet or more to dominate over any ambient fields present. Good candidates are an electric clothes drier or the oven element of an electric kitchen stove. Take a reading with the detector coil placed against some nearby surface (but not too close, so the coil's exact position won't be too critical) and mark or record the coil's position. Then if the coil is placed in that same position at a later date, the reading should be approximately the same.

A quick check of the linear mode calibration can be made by comparing it with that of the flat mode. To do this, a source of very pure 60 Hz (or 50 Hz) magnetic field needs to be located. (Such a source will produce a meter reading but only a very quiet 60 Hz hum. Possible candidates include an old-style synchronous motor electric clock or a high voltage transmission line.) In the presence of this 60 Hz source, the flat and linear mode readings should be very nearly the same.

Calibration

Before shipment, your 42B-1 Milligaussmeter (serial no. 1369) was calibrated at 50, 60, and 120 Hz, as follows:

Flat Mode:

Frequency	Mag. Field	Reading
50 Hz	30 mG	30 mG
60 Hz	30 mG	30 mG
120 Hz	30 mG	30 mG

Linear Mode:

Frequency	Mag. Field	Reading
50 Hz	30 mG	25 mG
60 Hz	30 mG	30 mG
120 Hz	30 mG	60 mG

(Note that the coil provided with this meter is marked with the last two digits of the serial number. Use of another coil with this meter may give slightly different readings —though two coils shipped at the same time are usually very close.)

MONITOR INDUSTRIES

6112 Fourmile Canyon, Salina Star Route, Boulder, Colorado 80302

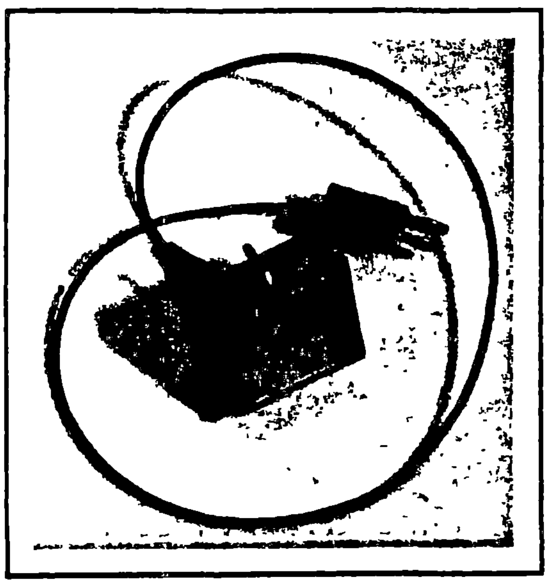
(303) 442-3773

For the professional user investigating the character of the field sources, and for the technically inclined layman, we offer :

The MSI-20/25 gaussmeter

The MSI-20/25 provides all the information of the MSI-25 meter plus additional frequency information previously available only in expensive meters.

How it works: The sensor has a toggle switch. The 25 position gives the correct mG reading for the power frequency sources. Switch to the 20 position. If the number on the display remains the same or is slightly lower, you are measuring a simple 60 Hz field. If the 20 position shows a higher reading, there is a harmonic frequency present (usually 180 Hz). The greater the difference in the two readings, the greater the amount of harmonic content (THD). The 20 sensor has a linear response to frequency up to 4 kHz, then a falling response. A frequency response curve is available for VLF measurements.



Additional information provided by the 20/25 sensor:

- To determine the predominant frequency present, plug the sensor into a frequency-reading multimeter such as the Fluke 83 or 85 or Goldstar 232 and switch to the 20 position. Read the frequency. (You can read both the ELF and VLF frequencies from a VDT).

- To view the wave forms being picked up by the 20 sensor, plug the extension lead into an oscilloscope. View the wave forms. For on-the-spot recording, you may use a Leader 300, a Fluke 97 or other portable digital oscilloscopes and record the wave form for later print-out.

- To record magnetic field strength maximum, minimum and average over 36 hours plug the sensor into recording multimeters such as a Fluke 83 or a Goldstar 9185, etc. For a complete record over a 24-hour or longer period, plug the sensor directly into a data logger. 1 mG = 1 mV AC. Inquire about MSI's new complete data-logging system for notebook PCs for under $400.00.

- MAGCHECK sensors can be used with other digital multimeters having a 200 mV AC setting (0.1 mV or 100 µV resolution). *Exception:* some True RMS meters with inaccurate lower ranges. See specs: "from 5% to 100% of range".

A carrying case is available as an option. See photo. An electric field accessory (E-100) is available for measuring electric field strength near power lines. A body voltage accessory (BV-1) is available for measuring the body's voltage induced by house wiring, power lines and appliances. 50 Hz versions of both MSI meters are available for other countries. For further information call MSI at (800) 749-9873. Our local Tucson phone is (602) 822-2355 and our fax is (602) 822-1640.

For information on our *measurement and consulting services* call ELF Magnetic Surveys at the same number.

To order: call **msi** at (800) 749-9873. MasterCard or Visa accepted. Overnight delivery available to all states. See price list for all options.

60 Hz MAGNETIC DOSIMETER

INSTRUCTION SHEET

Please read before operating meter

You have purchased a very accurate instrument for measuring the ***magnetic field Intensity*** (***magnetic flux density***) of power lines, appliances, transformers, outlets, cables, etc.. This meter "measures what it is calibrated for". You will not have to worry about harmonics (120, 180, 240 Hz, ...) causing an inflated reading. This meter maesures only 60 Hz (+/- 6 Hz). Harmonics produce a coil voltage that is 2, 3, or 4 times their actual amplitude (depending upon the harmonic number).

The meter has several dials and switches. The **large dial on the right** is for adjusting the ***maximum milligauss (mG) reading*** that the scale can display. When you are on the 2 milligauss scale, for example, the weakest signal that you can measure will be 1 microgauss.

The **Alarm Section** allows you to turn the **buzzer** "on" or "off". If "off", the alarm LED will be a little brighter than when both the buzzer and the LED are signalling a large reading. To set the alarm, push the **Set switch** "on" and adjust the **coarse** and setting to the alarm level that you wish.

With alkaline batteries, the meter will function for about 48 hours. When the battery is low, the **BAT indication** will appear on the LCD display, warning you that the battery voltage is low.

A **calibration service** is available and is recommended periodically. Ask for details before returning the 60 Hz magnetic dosimeter.

The bottom of the dosimeter has two jacks. The **right hand jack** (BNC jack) is for the probe attachment and the one next to it (the **RCA jack**) is for a stripchart recorder. A standard phon plug will work for taking the output to a stripchart or computer acquisition system (200 mV maximum output).

An AC adaptor is available for this unit shoud you wish to acquire long-term monitoring. It is comes as a kit with RCA rechargeable 9V batteries and plugs into the right side of the meter.

The fuse is a 0.5 Amp minifuse and should not need replacing under normal circumstances.

For service requirements, please call first:

ESSENTIA
100 Bronson Avenue / Suite 1001
OTTAWA, Ontario K1R 6G8
(613) 238-4437 FAX: **235-5876**

OPERATING INSTRUCTIONS

STEP 1: **Plug BNC probe jack.** (The metal jack at the end of the probe cable) onto the right hand jack on the meter. Twist the jack while pushing down to tighten.

STEP 2: **Turn the meter "on"** by pushing the ON/OFF (the switch just right of centre below the display) up towards the display. The LED display shopuld now read out numbers.

STEP 3: **Set the Alarm**. The meter is sent with the alarm set for three (3.0) milligauss. To set the alarm for a new activation point:

1) **Push the set switch** (upper left hand corner) up and hold it. The reading on the display is the current activation point of the alarm.

2) Now, while the set switch is being held up, **turn the coarse adjustment knob** (the top knob in the alarm section) to change the alarm activation point. Turn the knob clockwise to adjust the higher and counter-clockwise to adjust lower. Adjust until you are near the new activation point. Then, using the same procedure as with the coarse adjustment knob, use the **fine adjustment knob** (the lower knob in the alarm section) to obtain the precise activation point required.

3) **Release the set switch** (it should go down automatically). The display should now read out the magnitude of the magnetic field being read by the probe.

4) You can now chosse between the **alarm sounding** or the LED **lighting** up (located below the buzzer switch) when the field being read goes above the activating point.

   a) to have the alarm sound, push the **buzzer** switch (just left off centre) up toward the display.

   b) to have the LED light up *(the alarm will not sound)* push the **buzzer** button down ("off").

STEP 4: Now you are ready to **take magnetic field measurements**. This is done by pointing the end of the probe (the end not attached to the cable in the area you wish to measure and turning it around (360 °). As you are turning the probe, watch the readout on the LED display to get the highest reading. This is the maximum magnetic field in the area being measured. If the display is blank except for a one (1) in the leftmost end, then the field is too high to read in this scale. To **change scales**, simply turn the big knob labelled Milligauss clockwise to be able to take higher readings. Note, however, that as you go to higher scales, you lose decimal places and therefore lose accuracy.

STEP 5: Once you are done taking readings, be sure to **turn the meter "off"** by pushing the ON/OFF switch down.

ACCURACY AND CALIBRATION

Accuracy is scale-dependent. A 2 % accuracy on each scale is used. If, for example, you are measuring a signal on the 200 milligauss scale, your maximum error will be +/- 4 milligauss. If you are measuring on the 2000 milligauss scale, your maximum error will be +/- 40 milligauss. Be cautious about this in your measurements.

It is recommended that you remain with the largest number of digits in your readout to minimize your error.

An example would be reading 4.53 milligauss on the 20 mG scale instead of 4.5 mG on the 200 mG scale. Even though there is more fluctuation on the 20 mG scale, this is the more accurate scale to use for the above reasons. Accuracy is dependent upon the parts that are used (1% resistors in this unit) and upon the calibration procedure (a 1 % IEEE [Institute of Electrical and Electronic Engineers] calibration method for this unit).

Integrity Electronics Research Bulletin Vol. 1, No. 1
558 Breckenridge Street, Buffalo, NY 14222, 716-886-6985, 7283

TECHNIQUES FOR OBTAINING MAXIMUM READINGS ON A 60 HZ MAGNETIC FIELD METER

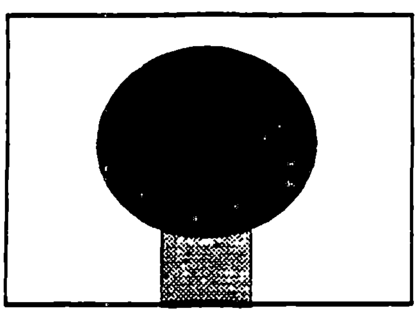
Findings from the 1988 Electric Power and Research Institute's (EPRI) Conference in Colorado Springs show that there is a strong preference in the scientific circles for finding the maximum reading when taking magnetic field measurements of 60 Hz fields. (Obtain the Proceedings from EPRI, P.O.B. 10412, Palo Alto, CA 94303.) Up until now, there has been some complaint about the difficulty of finding the maximum reading when taking on-site measurements.

Now, from the realms of algebra and geometry, we find a simple and reliable method for determining the maximum field intensity. Since any vector can be broken down into its x,y,z components, we can also build the vector by measuring its three components. It's as simple as $X^2 + Y^2 + Z^2$ and then take the square root.

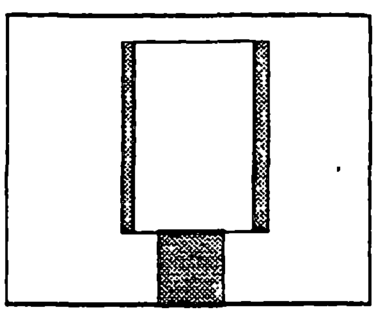
For those of you without the switchable, 3-axis probe (IER- 114), we show a method for orienting your probe to take the three measurements. For those with the Model 114 probe, just slide the switch from position X to Y to Z and take down the readings. (From experience, we find that the following method is <u>much easier</u> with much <u>more repeatable measurements</u> than the random motions necessary to "guess" at the direction for the maximum reading.) Prove to yourself that it works by searching for a maximum in a specific spot such as just at the surface of a desk. Then, take the X,Y, and Z measurements and with "Pythagorean's Theorem", find the RMS (root-mean-square) value or "hypotenus". See how close the two values are, showing that the component method works. If the values do not agree, you are in the vicinity of dominant circular polarization (see note below).

Caution! This method <u>does not work</u> in the presence of "circularly polarized fields" such as those found where <u>three-phase</u> power lines exist in close proximity. In other words, if you are outside, measuring the strength of the 60 Hz field with three power lines above you, you have to use the old guesswork method (which in many cases is a vertical field) to determine the maximum. Anytime you are indoors, however, you can be reasonably assured that circular polarization will not be a major contributing field, <u>except, of course</u>, when the outdoor three-phase high-voltage lines are within 100 feet of the house and dominating the home's exposure. (100 feet is a rough rule-of- thumb to follow.) Dietrich from Electric Research & Management, Inc. said at the conference that the RMS calculated value will be 40% greater than the actual maximum if in the presence of circularly polarized fields.

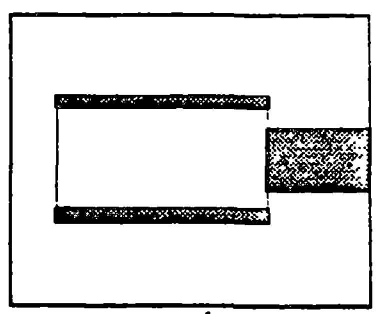
Use the Integrity Survey Sheets and fill in the blanks. Call if you have any questions.



X Reading



Y Reading

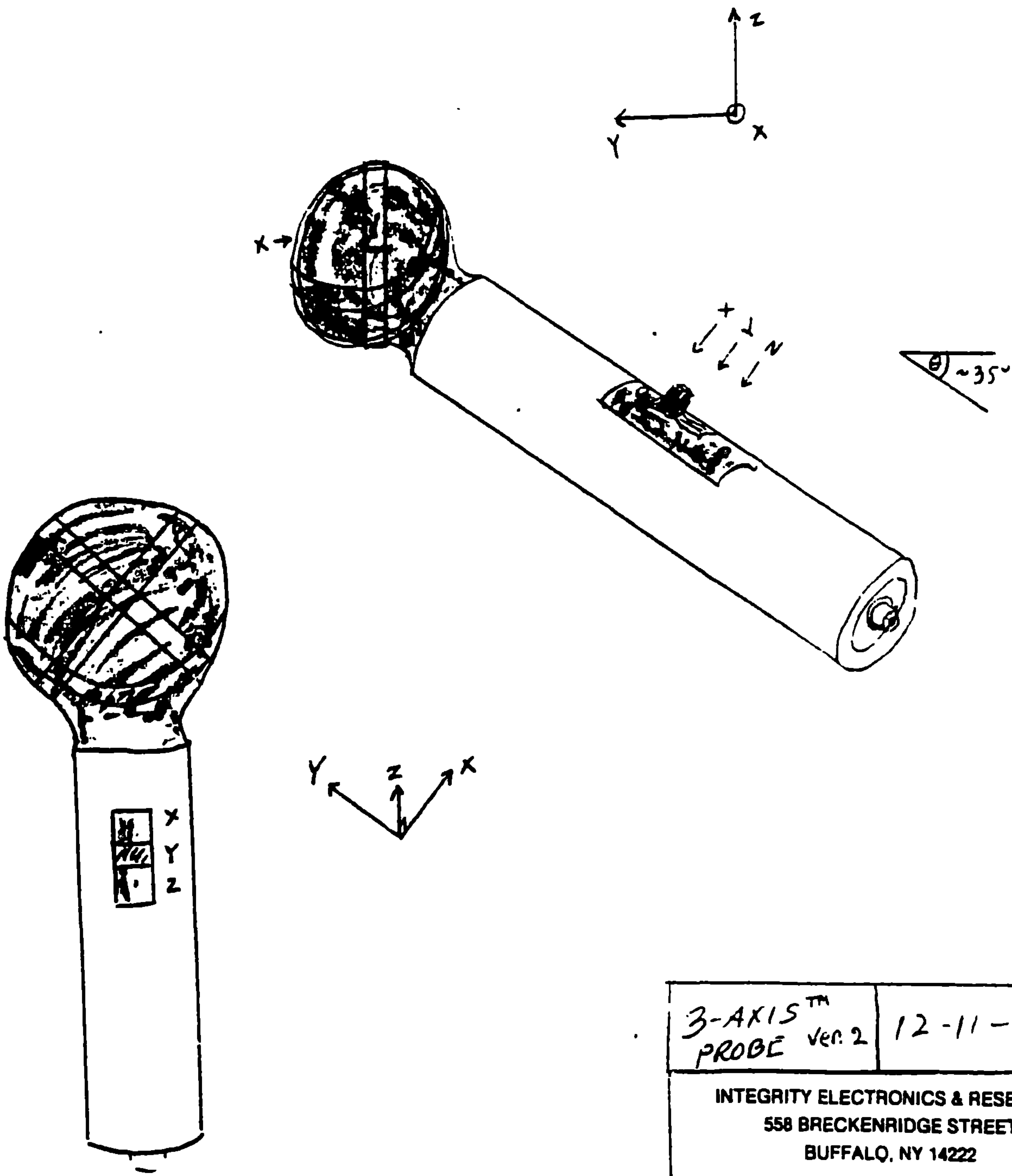


Z Reading

$$\text{RMS (MAXIMUM)} = \sqrt{X^2 + Y^2 + Z^2}$$

3-AXIS™ SWITCHING PROBE DESIGN
(IER-114)

- AIR COILS WITH SAME CONSTRUCTION AS SINGLE AXIS PROBE
- EQUIVALENT TO 3 SINGLE AXIS PROBES MOUNTED ORTHOGONAL TO EACH OTHER



3-AXIS™ PROBE Ver. 2	12-11-89

INTEGRITY ELECTRONICS & RESEARCH
558 BRECKENRIDGE STREET
BUFFALO, NY 14222

Integrity Design
& Research Corporation

296 West Ferry Street, Buffalo, New York 14213 Phone (716) 882-9699 Facsimile (716) 882-9699

From: Integrity Design & Research Corp.
296 West Ferry Street
Buffalo,NY 14213
Phone/Fax:(716) 882 9699
Tel: (716) 885 0011

To: PACE, Inc.
100 Bronson Avenue, Suite 1001
Ottawa Canada K1R 6G8

July 17, 1995

IDR-109 60 Hz Magnetic Dosimeter

calibrated today

B Field

100 mG theortical 101.00 mG actual
corrected

margin of error was 1 per cent after purchase in 1992.

United States
Environmental Protection
Agency

Air and Radiation
(NAREL)

400R-92-010
June 1992

EPA

Laboratory Testing of Commercially Available Power Frequency Magnetic Field Survey Meters

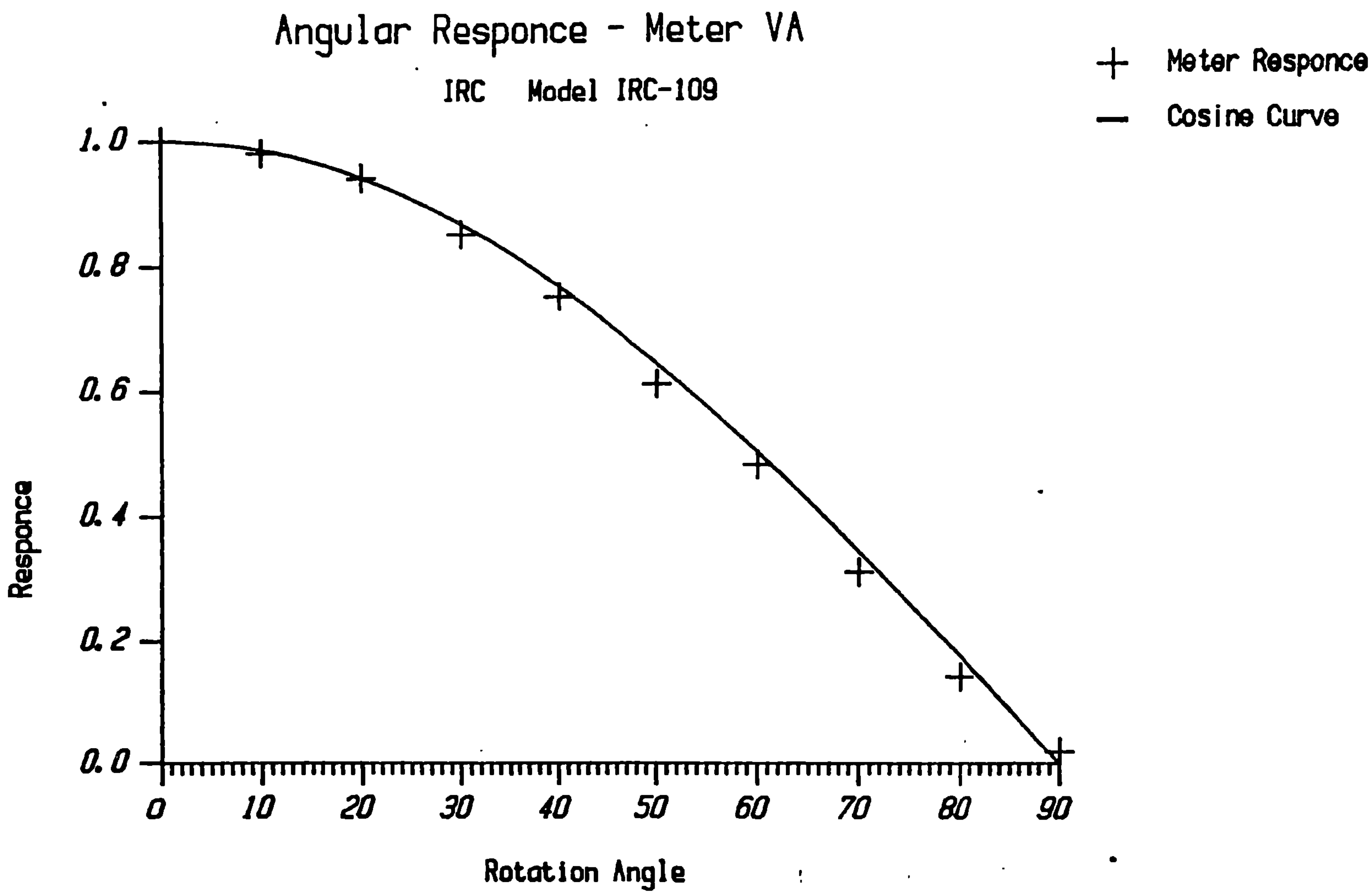
Final Report

Project Description

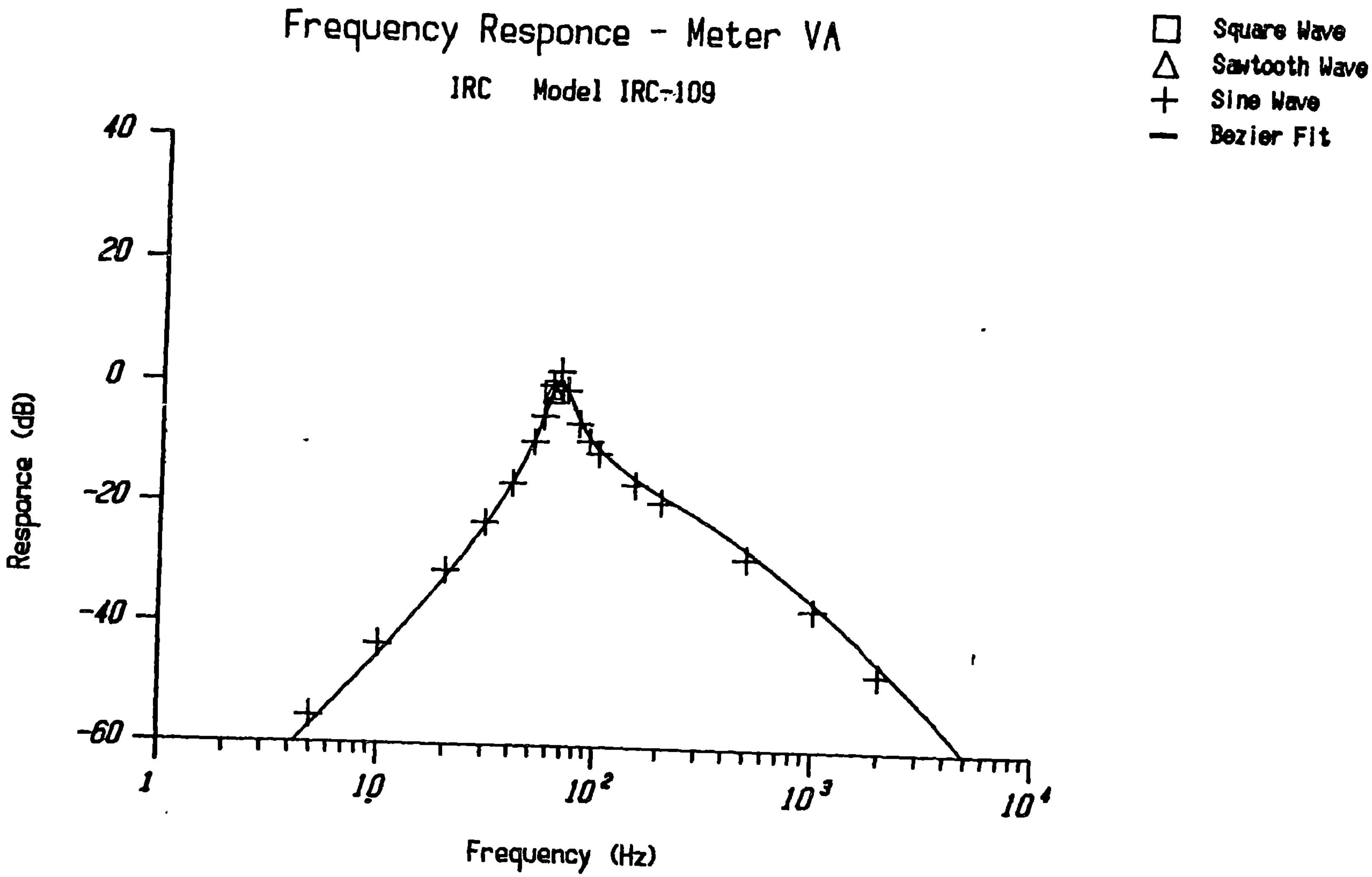
Recently, exposure to magnetic fields related to electrical power equipment has been implicated as a risk to the public. Many commercially available instruments may be used by the public to survey these fields in the environment. This testing effort was designed to determine the characteristics of these commercially available magnetic field survey meters.

This test series is part of an overall EPA effort to evaluate EMF instrumentation, establish standard measurement protocols, and work toward mitigation strategies. This project was performed in cooperation with the IEEE Magnetic Fields Task Force for the purpose of evaluating the performance of readily available single-axis, coil-type power frequency magnetic field meters. The project was centered at the EPA Electromagnetic Fields Laboratory in Las Vegas which developed the test systems used in this evaluation.

The test results show a broad range of meter characteristics and should be helpful for evaluation of a meter for various different applications. This report includes graphic representations of the results and has raw numerical data listed in the appendix.

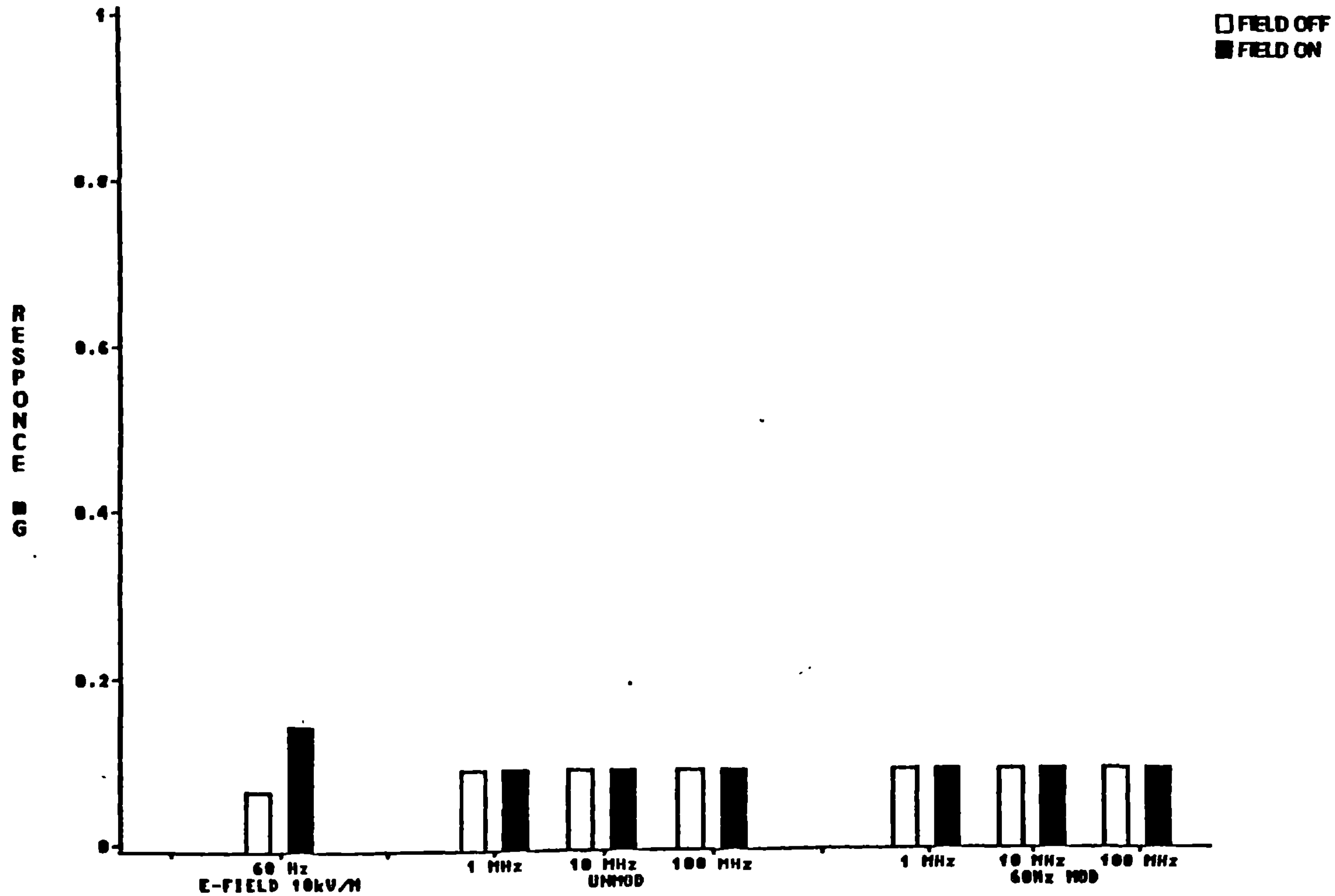


Angular Responce - Meter VA
IRC Model IRC-109
Meter Responce
Cosine Curve
Responce
Rotation Angle
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90


Frequency Responce - Meter VA
IRC Model IRC-109
Square Wave
Sawtooth Wave
Sine Wave
Bezier Fit
40
20
0
-20
-40
-60
Responce (dB)
1
10
10^2
10^3
10^4
Frequency (Hz)

Susceptibility – Meter VA

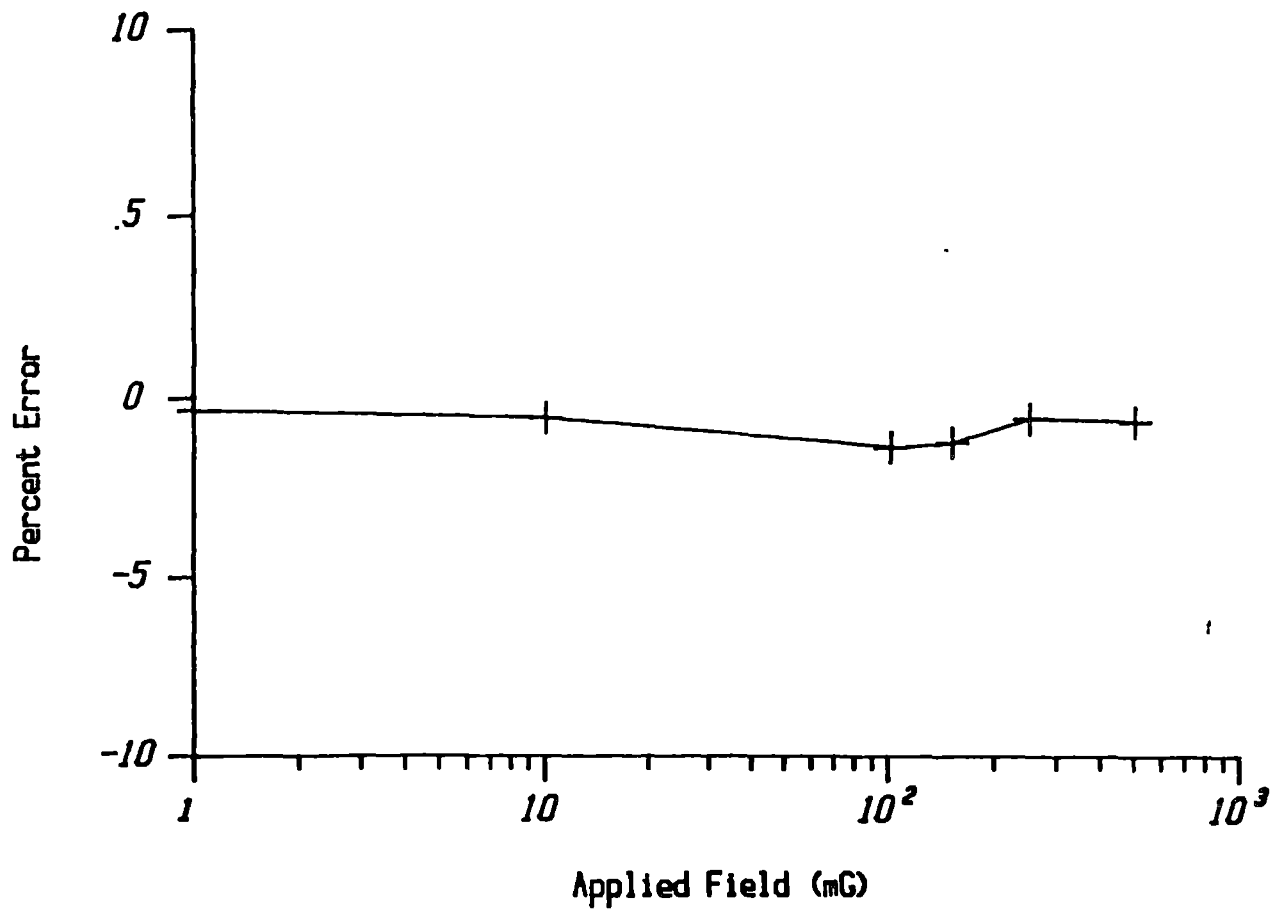
IRC Model IRC-109



5

Accuracy and Linearity - Meter VA

IRC Model IRC-109



IRC - MODEL IRC 109

METER CODE	MANUFACTURER	METER NAME	MODEL #	SERIAL #
VA	INTEGRITY DESIGN & RESEARCH CORP. 296 West Ferry Street BUFFALO, NEW YORK 14213 (716) 882-9699	60 Hz H Field	IRC-109	

METER ACCURACY AND LINEARITY AT 60Hz - TEST LOCATION LAB

Date	Time	Temperature	Meter Background- mG
Feb-11-91	12:40PM	76° F	0.2

RANGE SETTING	ACTUAL FIELD	MEASURED FIELD	% ERROR
2000 mG	503.73 mG	500.00 mG	-0.74%
	251.59 mG	250.00 mG	-0.63%
200 mG	151.94 mG	150.00 mG	-1.28%
	50.49 mG	50.00 mG	-0.96%
20 mG	15.04 mG	15.01 mG	-0.25%
	10.00 mG	9.99 mG	-0.10%

-0.66% AVG % ERROR

METER ACCURACY AND LINEARITY AT 60Hz - TEST LOCATION REMOTE

Date	Time	Temperature	Meter Background
Mar-21-91	01:10PM	51° F	0.072 mG

RANGE SETTING	ACTUAL FIELD	MEASURED FIELD	% ERROR
200 mG	101.43 mG	100.00 mG	-1.41%
	101.43 mG	100.00 mG	-1.41%
20 mG	10.07 mG	10.00 mG	-0.71%
	10.04 mG	10.00 mG	-0.39%
2 mG	1.00 mG	1.00 mG	-0.34%

-0.85% AVG % ERROR

IRC - MODEL IRC 109

FREQUENCY RESPONCE PRIMARY DATA

Date	Time	Temperature	Meter Background
Feb-11-91	02:50PM	76° F	0.13 mG

FREQUENCY	RANGE SETTING	ACTUAL FIELD	MEASURED FIELD	RELATIVE RESPONCE
1 Hz	20 mG	954.99 mG	0.14 mG	-76.37 dB
2 Hz	20 mG	954.99 mG	0.30 mG	-70.06 dB
5 Hz	20 mG	954.99 mG	1.62 mG	-55.41 dB
10 Hz	20 mG	954.99 mG	6.54 mG	-43.29 dB
20 Hz	200 mG	1015.70 mG	28.80 mG	-30.95 dB
50 Hz	200 mG	442.70 mG	150.00 mG	-9.40 dB
60 Hz	200 mG	151.99 mG	150.00 mG	-0.11 dB
100 Hz	200 mG	548.98 mG	150.00 mG	-11.27 dB
200 Hz	200 mG	1009.96 mG	109.30 mG	-19.31 dB
500 Hz	200 mG	1007.18 mG	38.70 mG	-28.31 dB
1 kHz	200 mG	1002.36 mG	14.70 mG	-36.67 dB
2 kHz	200 mG	1009.51 mG	4.40 mG	-47.21 dB
5 kHz	20 mG	794.91 mG	0.67 mG	-61.48 dB
10 kHz	20 mG	553.75 mG	0.13 mG	-72.59 dB

FREQUENCY RESPONCE AUXILIARY DATA

Date	Time	Temperature	Meter Background
Feb-11-91	01:33PM	76° F	2 mG

FREQUENCY	RANGE SETTING	ACTUAL FIELD	MEASURED FIELD	RELATIVE RESPONCE
70 Hz	2000 mG	278.02 mG	250.00 mG	-0.92 dB
80 Hz	2000 mG	514.63 mG	250.00 mG	-6.27 dB
90 Hz	2000 mG	725.41 mG	250.00 mG	-9.25 dB
40 Hz	2000 mG	1015.80 mG	155.00 mG	-16.33 dB
30 Hz	2000 mG	1010.56 mG	72.00 mG	-22.94 dB
65 Hz	2000 mG	194.14 mG	250.00 mG	2.20 dB
55 Hz	2000 mG	448.98 mG	250.00 mG	-5.09 dB
150 Hz	2000 mG	1008.79 mG	153.00 mG	-16.38 dB

FREQUENCY RESPONCE AUXILIARY DATA

Date	Time	Temperature	Meter Background
Feb-12-91	08:40AM	76° F	0.13 mG

FREQUENCY	RANGE SETTING	ACTUAL FIELD	MEASURED FIELD	RELATIVE RESPONCE
65 Hz	200 mG	116.49 mG	150.00 mG	2.20 dB
55 Hz	200 mG	270.52 mG	150.00 mG	-5.12 dB

IRC - MODEL IRC 109

METER 60Hz NON-SINUSOIDAL RESPONCE DATA

Date	Time	Temperature	Meter Background
Feb-12-91	09:12AM	76° F	0.2 mG

SQUARE WAVE TESTING

RANGE SETTING	ACTUAL FIELD	MEASURED FIELD	% ERROR	RELATIVE RESPONCE
200 mG	166.17 mG	150.00 mG	-9.73%	-0.88 dB
	166.10 mG	150.00 mG	-9.69%	-0.88 dB
			-9.71%	-0.88 db

SAWTOOTH WAVE TESTING

RANGE SETTING	ACTUAL FIELD	MEASURED FIELD	% ERROR	RELATIVE RESPONCE
200 mG	185.52 mG	150.00 mG	-19.15%	-1.85 dB
	185.69 mG	150.00 mG	-19.22%	-1.85 dB
			-19.18%	-1.85 db

SINE WAVE TESTING

RANGE SETTING	ACTUAL FIELD	MEASURED FIELD	% ERROR	RELATIVE RESPONCE
200 mG	151.74 mG	150.00 mG	-1.15%	-0.10 dB
	151.81 mG	150.00 mG	-1.19%	-0.10 dB
			-1.17%	-0.10 db

METER ANGULAR RESPONCE DATA

Date	Time	Temperature	Meter Background
Feb-12-91	09:32AM	76° F	0.13 mG

Angle	ACTUAL FIELD	MEASURED FIELD	ANGULAR RESPONCE
0°	151.66 mG	150.00 mG	1.00
10°	154.07 mG	150.00 mG	0.98
20°	161.38 mG	150.00 mG	0.94
30°	177.25 mG	150.00 mG	0.85
40°	200.20 mG	150.00 mG	0.75
50°	245.38 mG	150.00 mG	0.61
60°	311.70 mG	150.00 mG	0.48
70°	480.97 mG	150.00 mG	0.31
80°	1006.95 mG	146.80 mG	0.14
90°	1076.45 mG	24.00 mG	0.02

METER 60Hz E FIELD SUSCEPTIBILITY DATA

Date	Time	Temperature
Feb-27-91	11:20AM	74° F

	E Field OFF Reading	E Field ON Reading
EFM Metex	0.00	10.0 kV/M +-5%

		E Field OFF Reading(mG)		E Field ON Reading(mG)
		Meter Range		Meter Range
		2mG		2mG
Trial Number	1	0.06		0.15
	2	0.06		0.14
	3	0.06		0.13
	4	0.06		0.15
	5	0.06		0.13
		0.06	AVG	0.14

		E Field OFF Reading(mG)		E Field ON Reading(mG)
		Meter Range		Meter Range
		20mG		20mG
Trial Number	1	0.08		0.15
	2	0.08		0.16
	3	0.08		0.16
	4	0.08		0.18
	5	0.08		0.14
		0.08	AVG	0.16

		E Field OFF Reading(mG)		E Field ON Reading(mG)
		Meter Range		Meter Range
		200mG		200mG
Trial Number	1	0.20		0.30
	2	0.20		0.30
	3	0.20		0.30
	4	0.20		0.30
	5	0.20		0.30
		0.20	AVG	0.30

		E Field OFF Reading(mG)		E Field ON Reading(mG)
		Meter Range		Meter Range
		2000mG		2000mG
Trial Number	1	0.20		0.20
	2	0.20		0.20
	3	0.20		0.20
	4	0.20		0.20
	5	0.20		0.20
		0.20	AVG	0.20

Appendix VA

RADIO FREQUENCY SUSCEPTIBILITY MEASUREMENT DATA - UNMODULATED

Date	Time	Temperature
Feb-22-91	01:00PM	80° F
	RF OFF Reading(mG)	RF ON Reading(mG)
	Meter Range	Meter Range
	2mG	2mG
1 MHz	0.08	0.08
10 MHz	0.08	0.08
100 MHz	0.08	0.08

RADIO FREQUENCY SUSCEPTIBILITY MEASUREMENT DATA - 60 Hz MODULATED

Date	Time	Temperature
Feb-22-91	02:05PM	80° F
	RF OFF Reading(mG)	RF ON Reading(mG)
	Meter Range	Meter Range
	2mG	2mG
1 MHz	0.08	0.08
10 MHz	0.08	0.08
100 MHz	0.08	0.08

IRC - MODEL IRC 109

MINIMUM DETECTABLE SIGNAL

Date	Time	Temperature		Meter Background	
Mar-21-91	01:30PM	53° F	min	0.058	mG
			max	0.075	mG

		Threshold Current mA	Threshold Field uG
Trial Number	1	1.50 mA	80.93 uG
	2	1.70 mA	91.72 uG
	3	1.20 mA	64.74 uG
	4	1.20 mA	64.74 uG
	5	1.50 mA	80.93 uG

NOTE: Meter readings increase by about 0.04mG 76.61 uG AVG THRESHOLD FOR SENSITIVITY

METER RESOLUTION DATA

Date	Time	Temperature		Meter Background	
Mar-21-91	01:37PM	53° F	min	0.2	mG
			max	0.3	mG

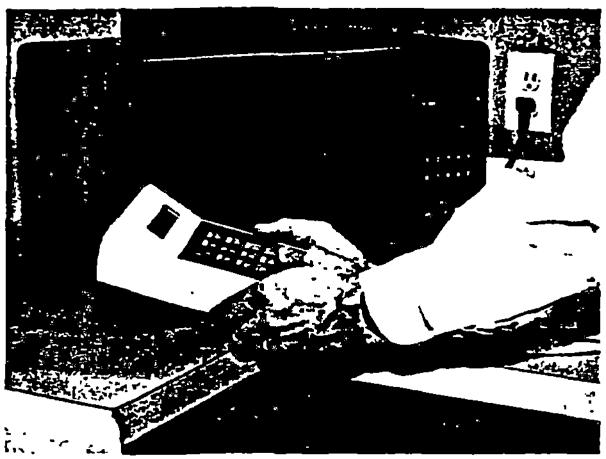
Meter Range Auto Range - 100mG

		Drive Current Start A	Threshold Current A	Resolution uG	Resolution %
Trial Number	1	1.8840 A	1.8910 A	377.64 uG	0.37%
	2	1.8840 A	1.8910 A	377.64 uG	0.37%
	3	1.8840 A	1.8910 A	377.64 uG	0.37%
	4	1.8840 A	1.8910 A	377.64 uG	0.37%
	5	1.8840 A	1.8910 A	377.64 uG	0.37%

NOTE: Meter readings increase by 0.3mG 377.64 uG 0.37%

The **FIELD STAR™** is a multiple function hand held recorder for logging 60 hertz magnetic fields. Three orthogonal sensing coils measure the magnitude of the magnetic field component along the x, y and z axes. The **FIELD STAR** can be used as a survey instrument or as a data logger recording magnetic field data as a function of time or distance. Complete maps of magnetic field strength can be made of any area or building, such as in a residence or under a distribution line.

Dexsil® has improved the EPRI STAR technology and made the **FIELD STAR** more versatile and user friendly, incorporating improvements suggested by experience gained in the field.



Cover Photo by Vasu Tahiliani

SPECIFICATIONS:

MEASURED QUANTITIES:
True RMS value of the 60 hertz component along the three orthogonal axes and the magnitude of the resultant field vector.

SENSITIVITY:
The **FIELD STAR** has 3 internal ranges automatically set by the microprocessor. The resolution achieved in the 0-10mG range is 0.04 mG and better than 1% of full scale for the ranges 10-100mG and 100-1000 mG.

DISPLAY:
The 2x16 Alpha-Numeric display can be programmed to display the magnitudes of the x, y, z components and the resultant vector.

MEMORY:
The **FIELD STAR** has 128K CMOS—RAM with 10 year battery backup for data storage. This equates to approximately 16,000 data points (depending on the number of separate files) with time or location information and the x, y and z axis field components.

PROGRAM STORAGE:
The on-board software is stored in EPROM. The program and calibration data are therefore protected from loss of battery power.

COMMUNICATION:
Serial RS-232 port for up-loading data to an IBM PC or compatible.

POWER SUPPLY:
The **FIELD STAR** is powered by two 9 volt batteries.

DATE AND TIME:
The on-board clock/calendar keeps track of real time and date and needs only to be set once.

DIMENSIONS:
Length = 7.5", width = 4", height = 2.75"

Field Star and Dexsil are Trademarks of Dexsil Corporation

FUNCTIONS:

DISPLAY MODE:
The **FIELD STAR** can be used to display the three orthogonal components and the resultant simultaneously. With an update rate of once every second, real-time data can be used to locate field sources.

TIMED DATA SAMPLING MODE:
In the timed sampling mode, the **FIELD STAR** can be used much the same as in the display mode but stores the field readings in memory. Each location can be labeled by simply pressing the enter button. The unit can be turned off between readings to facilitate moving to a new building or site. New data will be automatically appended to the existing data with a unique file label. The current file number is displayed as each file is opened to make record keeping easier, and the current data label within each file is displayed at each reading.

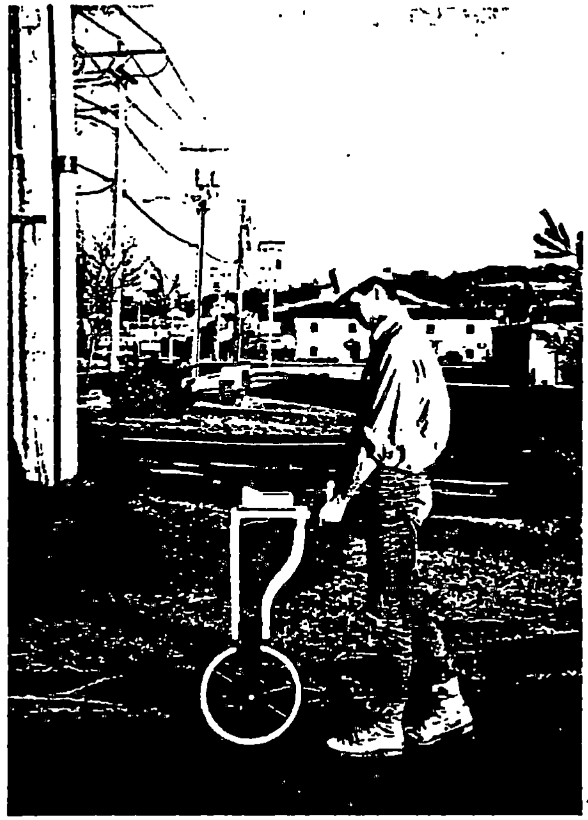
For long term logging in an office or residence, sampling intervals of any multiple of minutes can be chosen and the device can be left unattended and retrieved days later. The auto ranging feature ensures that the maximum resolution is achieved for each sample.

DISTANCE SAMPLING MODE:
When combined with the mapping wheel the **FIELD STAR** can be programmed to record data at equally spaced intervals along a path, such as along a right of way or property line. Data blocks can be labeled as in the timed sampling mode using the enter button.

MAPPING MODE:
Using the **FIELD STAR** mapping wheel combination, complete maps can be made of a residence, right of way, or property. In the mapping mode, the **FIELD STAR** stores samples every foot along the path. As each turn is made, the turn is entered using the keypad and automatically stored with the field data for reconstruction of the mapping path on a PC.

NEW FEATURES INCLUDE:

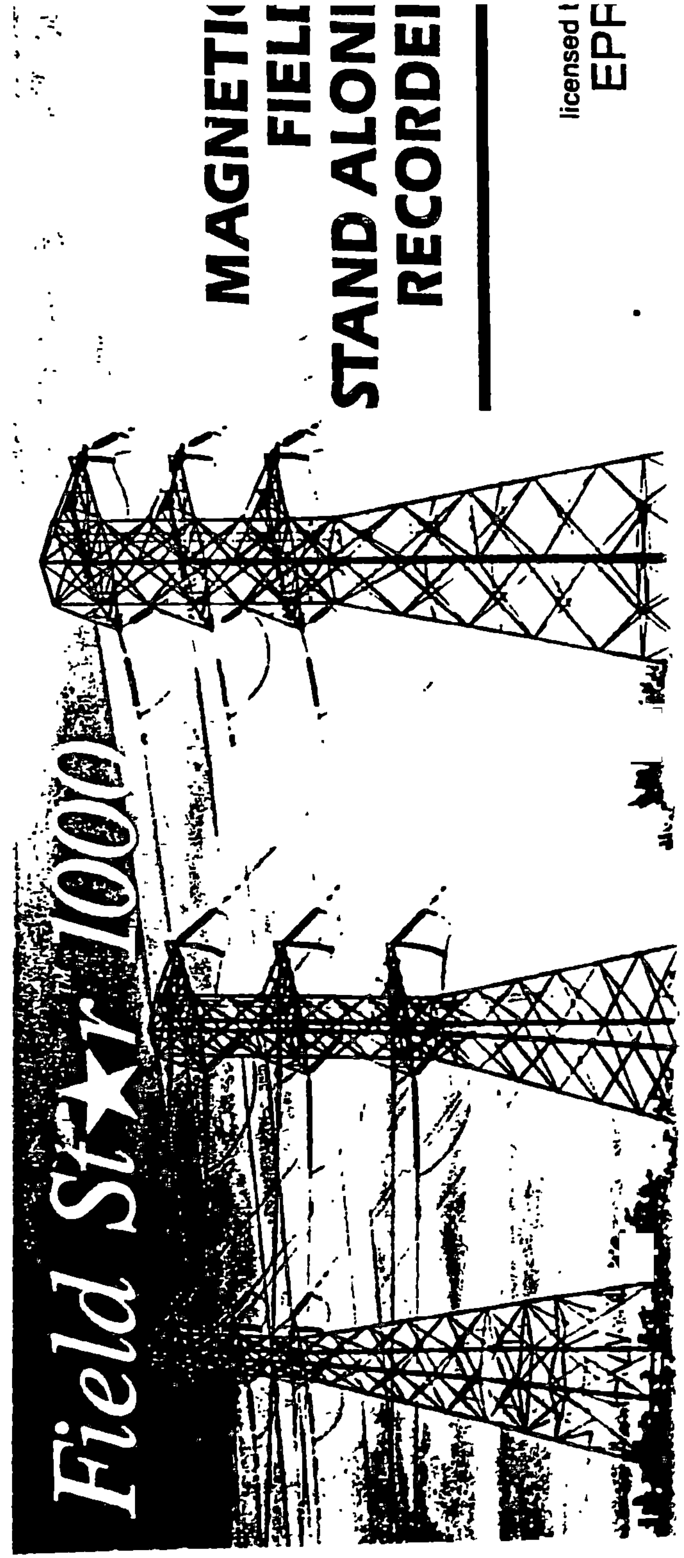
- 2x16 Alpha-Numeric LCD
- 128k CMOS-RAM data storage for up to 16,000 samples
- 10 year battery backup for stored data
- 12 button keypad
- EPROM program storage
- Dynamic range of 0.05-1000 mG
- Complete auto ranging
- On-board Clock/Calender for real time reference
- Flexible on-board program that allows menu options to be selected from the display without powering off or interfacing with a PC.
- The capacity to store mixed types of data files. This allows complete mapping, spot readings and time sampled data to be stored for one or more locations without up-loading data.
- Improved graphics software



The **FIELD STAR** incorporates technology developed for the Electric Power Industry under the sponsorship of EPRI, the Electric Power Research Institute. Dexsil has a commercialization license to manufacture the **FIELD STAR** and related products.

DEXSIL

DEXSIL CORPORATION
One Hamden Park Drive • Hamden, CT 06517
Tel. (203) 288-3509 • Fax (203) 248-6523



D E X S I L   C O R P O R A T I O N
ONE HAMDEN PARK DRIVE
HAMDEN, CT 06517
(203) 288-3509

C E R T I F I C A T E   O F   C A L I B R A T I O N

The following device has been calibrated using a two meter square coil as described in ANSI/IEEE Std 644-1987.

Model Number: FS1000
Serial Number: 31400218
Filter Frequency: 55-65Hz(@ 3dB)
Calibration date: 05-03-1993

Calibration Field (mGauss)	X Channel Reading (mG)	Y Channel Reading (mG)	Z Channel Reading (mG)
8.7535	8.76	8.76	8.76
82.935	82.8	82.8	82.8
805.32	804	804	804

Each axis is aligned with the calibration field and point matched at the field strengths in the above table. All readings are rms averages.

Electric Field susceptibility is less than 1 bit in all ranges at 10kV/m.

John P. Rosadini
John P. Rosadini, Engineer

CHANGING THE BATTERY

The battery is a 9-volt rectangular type. The alkaline type will last about 30 hours of continuous use, while the transistor type will last about 10 hours. Turn the meter OFF, unscrew the back (four screws) and slowly separate the back cover. DO NOT PULL APART RAPIDLY - it may break the wires. Disconnect the battery and slide it out by pushing it out from the back. Then replace it. Reconnect the new battery and reassemble. Leave the meter OFF when not in use; even "Battery Test" will draw some power.

SPECIFICATIONS

The MAGNETIC and ELECTRIC field settings are frequency-weighted from 30 to 500 Hz and are calibrated at 60 Hz. For example, a 60 Hz magnetic field with a strength of 2 milligauss will read "2" on the meter, but 120 Hz at 2 milligauss will read "4" on the meter. This is to gauge the currents induced inside the body, which are proportional to field strength multiplied by frequency. From 500 Hz to 1000 Hz, the response is flat +/-20%. Above 1000 Hz, the magnetic and electric sensitivities of the meter slowly decrease with increasing frequency, falling to zero near 100 KHz, but with some residual sensitivity up to 100 MHz. In theory, the body's sensitivity to fields should begin to decrease at frequencies above about 500 Hz. Accuracy is +/-20% of scale reading for MAGNETIC, and +/-30% for ELECTRIC (RMS @ 60 Hz).

RADIO/MICROWAVE is sensitive from 50 MHz to 3 GHz and is calibrated at home microwave oven frequency (2 GHz). The accuracy is -50% to +100% because of the unpredictable effect of reflections within the room and off the user.

WARRANTY

The unit is warranted against defects in materials and assembly for one year from the date of purchase. Customer should return defective unit, shipping prepaid, for repair or replacement.

DISCLAIMER

Use of the meter is solely at the user's discretion to identify personal exposure to nonionizing electromagnetism of the strength and types believed (as of May 1992) to pose a possible health risk. Because a meter of this type may malfunction, the user's responsibility is to determine if the meter is working properly by using it to measure a known reference (see CALIBRATION section of this booklet). Manufacturer or dealer cannot assume responsibility for damages resulting either from a defective meter (except to replace or repair said meter within the warranty period) or from inaccuracies in the present body of knowledge concerning the health hazards of electromagnetism.

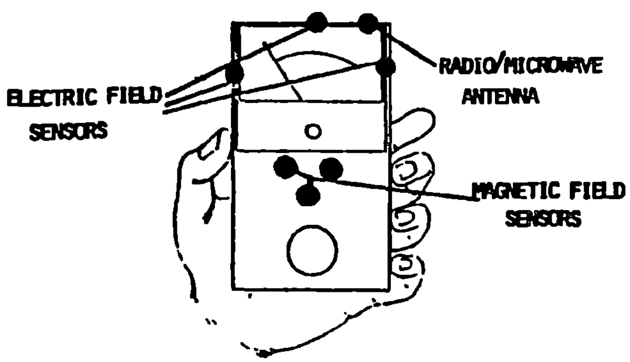
The meter should be used so that simple steps (such as moving furniture) can be taken to reduce relative exposure within a home or office. If more drastic actions are contemplated, remember that *some readings in the HIGH (red) zone may ultimately prove not to pose a health risk*, so consult expert advice before taking more drastic steps, and *perform independent tests with another type of meter.* Remember that the TriField® meter is frequency-weighted, so in most environments, it will read higher in the magnetic field setting than a more traditional meter of the type used in epidemiological studies to set possible hazard thresholds.

TriField® Meter Instructions

TAKING READINGS

Hold the meter as shown. This prevents your hand from shielding electric fields or microwaves. (Your hand cannot shield magnetic fields.) Read the *top* scale when the knob is set on "MAGNETIC (0-100 range)", or on "ELECTRIC". This top scale reads 0-100 milligauss when on "MAGNETIC (0-100 range)", or 0-100 kilovolts per meter when on "ELECTRIC". For more sensitivity to weak magnetic fields, set knob on "MAGNETIC (0-3 range)", and read the *center* scale. When the knob is turned to "RADIO/MICROWAVE", use the bottom scale (.01-1 milliwatt per square centimeter) and point the meter toward the radio/microwave source.

Avoid long term personal exposure to HIGH (red scale) readings in any setting; they pose a possible (but not yet certain) *health risk. The dotted red scale is border*-line exposure, and probably poses little if any health risk. Below that is generally regarded as safe for continuous exposure.



BATTERY TEST

Switch the knob to "Battery Test". If the battery needs replacement, the needle will be to the left of the line that is itself left of the words "Batt. Test".

CALIBRATION

The ELECTRIC and RADIO/MICROWAVE settings should be low (below the dotted red scale) in most parts of homes or offices, especially if you cup your hand in front of the meter or place the meter in a metal box. In the country, far from power lines, the magnetic field should also read very low (below .2 milligauss).

High Magnetic Field Sources

Hold the meter near these sources, and set the knob on "MAGNETIC (0-100 range)". Some of these should read greater than 10 milligauss on the top scale. Your body or hand does not shield these.

- AC wall adaptors
- Vacuum cleaner or motorized equipment
- TV screens
- Motorized clocks (120 Volt)
- Lightning
- Inside of commercial jets
- Running cars, especially near front floorboard

If you can't get a reading greater than 10, test the battery. (If the battery is bad, the meter needle cannot go up to full scale.)

High Electric Field Sources

Switch the knob to ELECTRIC. If you point the top surface of the meter box (the surface furthest from your hand) toward these sources, some should read greater than 3 kilovolts per meter. (Notice that your body can easily shield electric fields; the reading is lower if you cover the top surface of the meter with your hand. Also, the presence of your hand at the back of the meter *compresses* the electric field, making it read somewhat higher than if the meter were held in that position hanging by a string.)

- TV screens
- Improperly grounded electrical equipment
- Single "hot" wire, even if insulated
- Flourescent lights
- Electric Blankets, when plugged in, but "off", especially if the AC plug polarity is reversed

High Radio/Microwave Power Sources

Switch to RADIO/MICROWAVE and *point the top (front) of the meter toward* the following sources. Read the bottom scale. Your hand can shield the higher frequencies (microwave) but not lower frequencies.

- Cellular phone*
- CB or amateur radio transmitter*
- Microwave ovens near door seal A reading of more than .2 mW/cm^2 (needle halfway up) at a distance of six feet suggests a leaking microwave door seal, which should be repaired.

* *Will also produce electric and magnetic field readings. An ordinary radio phone however, will produce little or no needle deflection.*

Electromagnetic Measurements and the TriField® Meter

Direct and indirect evidence suggests that AC electric and magnetic fields increase the risk of certain cancers and other physiological and psychological abnormalities. Although how this happens is not fully understood, both magnetic and electric AC fields that surround the body can produce AC electric current inside the body. The best available theory is that this current interferes with the normal transport of ions across cell membranes.(1)

At a continuous exposure of about one billionth of an amp of AC current per square centimeter (give or take a factor of three), biological effects begin to be observed. Very preliminary results show that at five times that level, for example, an increase in protein production in cancer cells is seen; but when the field is increased 1000 times further, the increase in protein production is only three times greater (**not** 1000 times greater). These changes are seen for AC current at several different frequencies, including 60 Hz (60 oscillations per second).(2)

If the cell-membrane-interference theory is correct, the body should be sensitive to current at any frequency up to about 1000 Hz (the exact upper limit frequency is not known and experimental measurement of it has not been attempted).

Based on the above evidence and some epidemiological studies(3), it would be prudent to avoid continuous exposure to any electromagnetic pollution that produces AC current inside the body higher than one billionth amp per square centimeter, at frequencies of 1000 Hz or below. (No absolute hazard threshold has been established yet, but the lower limit for biological effects is probably between one-third and three times that level). Preliminary results suggest also that it's better to spend a short time well above this threshold than a long time just above it.) At frequencies above 1000Hz, the body is likely also to be sensitive, but not as sensitive as it is to lower-frequency currents.

An external magnetic field of 3 milligauss or an electric field of 2.5 kilovolts/meter at 60 Hz will produce approximately one billionth amp per square centimeter. The current produced inside the body is proportional to field strength times frequency, so at 120 Hz (twice the frequency), only half as much field (i.e.,1.5 milligauss and 1.25 kilovolts/meter respectively) is required to produce the same current inside the body. Interestingly, a fairly strong magnetic field (500 milligauss) and electric field (about 2 kilovolts/meter) exist in nature, but these fields are **static**, and thus have a frequency of zero--they produce no current inside the body.

Therefore, an electromagnetic pollution meter should be **frequency weighted**, meaning that it reads the product of magnetic field strength times **frequency** and/or electric field strength times **frequency**, if it is to gauge whether the electric current inside the body exceeds a threshold level. This frequency-weighting should extend up to about 1000 Hz and then the meter sensitivity should decrease at higher frequencies.

Magnetic and electric fields are vector quantities. This means they are specified as having a magnitude (or field strength, measured in milligauss or kilovolts/meter respectively) as well as a direction (an "arrow" showing which way they are pointing). The effect on the body is more or less independent of the direction of the field; only the **magnitude** is important. Virtually all field meters read the field strength in one direction only. The sensor of these meters must be pointed in the same direction as the field happens to be pointing; otherwise the meter will read less than the true magnitude of the field strength. If the sensor is pointed perpendicular to the local field direction, the meter will read zero, no matter how strong the field is. Then it will completely miss the field. To avoid this inaccuracy, a meter should read the true magnitude of the field, so a user could walk through a room with a meter and get an accurate, immediate reading of the field magnitude at every point along the path, regardless of which way the meter is oriented.

The TriField meter combines all the features needed for fast, accurate screening of electromagnetic pollution. It independently measures electric field and magnetic field **and is properly scaled for both, to indicate the full magnitude of currents produced by each type of field inside the body.** As a result, it "sees" much more than any other electromagnetic pollution meter. Depending on where the knob is set, it detects either frequency-weighted magnetic fields (two separate scales) or frequency-weighted electric fields in the ELF and VLF range (it has significant sensitivity at 100,000 Hz, well past the 17,000 Hz horizontal scan of video displays). It also has a setting which lets you gauge radio wave power all the way up to three billion Hz (3 GHz), which includes home microwaves (2 GHz), CB and cellular phone equipment, and many radars.

The TriField meter is the only one which combines magnetic, electric, and radio/microwave detectors in one package, so the entire nonionizing* electromagnetic pollution spectrum is covered. In addition, the magnetic setting and the electric setting measure **true magnitude**, a feature found elsewhere only in very expensive meters. If you hold the meter in the center of a room and tip it to various angles, the magnetic reading will stay approximately the same (+/- 15% typical) regardless of which way you tip or rotate it. The electric reading is similar, although the presence of your body alters the actual electric field, so readings will vary more. The radio/microwave setting reads full power radiated into the front of the meter.

Surprisingly, the TriField meter is one of the least expensive meters available. The few other meters below $200 read **only** low-frequency magnetic fields and **only** one direction (not true magnitude). The magnetic section of the TriField meter has three field- detecting coils pointing in the X, Y, and Z directions. A circuit amplifies these signals and gives them the proper frequency-weighting (sensitivity increases linearly from 30 Hz to 500 Hz, it stays level to 2000 Hz, then it falls off slowly to near zero at 100,000 Hz, but with some residual sensitivity up to 100 MHz). A unique network combines the three coil outputs nonlinearly to approximate a true magnitude. The meter is sensitive from .2 to 100 milligauss full scale at 60 Hz (or .1 to 50 milligauss full scale at 120 Hz, etc.) with a resolution of .2 milligauss in the sensitive range. Accuracy is +/-20% at mid-range.

In most homes and offices, a large fraction of the total magnetic field is at frequencies above 60 Hz. A TriField meter, when exposed to a 3 milligauss field, will read "3" if the frequency of the field is 60 Hz, but it will read "6" if the 3 milligauss field is at 120 Hz. In contrast, a non-frequency-weighted meter will read "3" in both cases, and a 60 Hz-only meter will read "3" and "0" respectively (even though in the 120 Hz case, the current induced in the body is **twice** as much.) This underscores a problem with present epidemiological studies of magnetic field health effects: generally, non-frequency-weighted meters (or even 60 Hz-only

*"Nonionizing," because this meter does not read nuclear radiation.

meters) were used. Indications are that in homes where these meters read consistently above 3 milligauss*, the chance of developing certain cancers is increased. Depending on the distribution of frequencies (which was **not** recorded in the studies), a TriField meter would generally read between "3" and "9" if the other meters read "3". Consequently, the threshold for the TriField might be more appropriately placed as high as "9" milligauss, with the uncertainty arising because previous studies did not measure frequencies above 60 Hz in a standard or uniform way.

The electric section consists of four metal plates under the meter face. Because the meter housing is plastic, the electric fields can go through to the plates, which are also arranged to detect AC electric fields in the X, Y, and Z directions. Circuitry similar to the magnetic section converts the signals into an electric field signal which is frequency-weighted. Sensitivity is .5-100 kilovolts per meter at 60 Hz, with resolution of .5 kilovolt/meter. Accuracy at mid-range is +/-30%.

Radio and microwaves are composed of a particular combination of electric fields and magnetic fields that is self-sustaining. For frequencies below about 100 MHz (100 million Hz) the principle effect on the human body is from the magnetic field part only. This is because the electric field component of radio waves produces much weaker currents in the body than does the magnetic field unless the wavelength of the waves is smaller than the height of the body. Low-frequency electric fields **by themselves** can be strong enough to create significant current, but only if they are from sources other than radio waves.

The radio/microwave section has a small L-shaped antenna in the front. The signal is amplified and converted to a power density magnitude, calibrated at typical home microwave oven frequency (2 GHz). It reads 0 to 1 milliwatt/square centimeter. The resolution in the low range is .01 mW/cm^2, which is the Russian standard for maximum safe microwave exposure to avoid changes in brain activity(4), and is the most conservative standard of any country. (The new OSHA safety threshold, as of 1-1-93 is 1 **mW/cm^2**, down from the previous 10 mW/cm^2). Typical accuracy is within a factor of two. Variations are caused by reflections off the user's hand and body.

A knob on the front has six positions: OFF, BATTERY TEST, two MAGNETIC field sensitivities (.5-100 milligauss at 60 Hz, and .2-3 milligauss at 60 Hz, to measure low fields more accurately), ELECTRIC field and RADIO/MICROWAVE power density. The meter face is analog (needle type). A needle reading of one-third of full scale corresponds to either .6 milligauss or 3 milligauss @ 60 Hz, 3 kilovolts/meter @ 60 Hz, or .04 mW/cm^2 respectively in the magnetic, electric, or radio/microwave field settings. Long-term personal exposure to levels higher than these should be avoided, so the meter is labeled "HIGH", above these levels. Unfortunately, because of uncertainty of population studies, the true health-effect threshold may be as low as 1 milligauss or as high as 10 milligauss.

In most homes or offices, some areas are "hot" spots with readings in the HIGH range. Most often, this is caused by magnetic fields, which come largely from unpaired internal wiring. (Contrary to popular belief, outside power transmission lines and transformers do not generally contribute as much magnetic field as does internal wiring.) Other magnetic sources include video displays, motorized clocks and other equipment, electric blankets and heaters, fluorescent lights and light dimmers, and

*A new Swedish study suggests 1mG is a better safety threshold.(5)

the transformers that are inside consumer devices. Many of the effects are from frequencies that are **harmonics** or **multiples** of 60 Hz (120 Hz, 180 Hz, etc.) and 17,000 Hz of video displays. Magnetic fields are difficult to shield, and either sheets made of specialized metal, or electronic instruments which actively produce magnetic fields to counter ambient fields, are required.

A few areas in most homes read HIGH in the electric field setting. These include areas near improperly grounded equipment, the front of video screens, and fluorescent lights. Most of these fields are at 60 Hz. Unlike magnetic fields, electric fields can be easily shielded using a grounded metal screen or foil; VDT screens of this type are readily available. You can greatly reduce the strength of an electric field just by placing your hand in front of the source. This effect can be seen using a TriField meter.

Occasionally, certain areas read HIGH in the radio/microwave setting. These include door seals around microwave ovens, and cellular phones (but **not** regular radio phones, which are very low-power). Radio/microwaves can be shielded in the same way as electric fields, although the lower frequency radio waves are not shielded by your hand as easily as microwaves are. (Metal screens will shield both.) In the U.S., radars and FM transmitters can legally expose residents to moderately high power levels, but such exposure is not common.

By seeing "hot" spots in your home or office, you can move furniture, cribs, or beds to reduce exposure. You can also take corrective action to avoid long term exposure to appliances that emit high electromagnetic pollution levels. If you have unusual sensitivity to a particular type of field, you can identify where problems exist (e.g., wearers of pacemakers should avoid even brief exposure to high radio/microwave power levels. Some anecdotal evidence indicates that brief exposure to very high AC electric or magnetic fields may cause nervousness or seizures in some people.)

The TriField meter comes with a one-year limited warranty and a 9-volt transistor battery included. This type of battery lasts about 10 hours (total measurement time). When the BATTERY TEST reads low, it can be replaced with any rectangular 9 volt transistor or alkaline (which lasts about 50 hours) type.

The meter is manufactured in the USA. TriField is a registered trademark of W.B. Lee.

(1) EPA Draft report March 1990. See Nature, vol.345, 6-7-90, Pg. 463.

(2) Science News, vol.137, no.15, pg. 229, April 14, 1990. This assumes average body resistivity of 150 ohm-cm.

(3) Several studies are in the literature. For example, The Lancet, January 29, 1983, pg.246; New England Journal of Medicine, vol. 307, no.4, July 22, 1982, pg.249.

(4) See The New Yorker, June 12, 1989, pg. 69; and Cancer Research, August, 1988, pg. 4222.

(5) In a study of about 500,000 people, continuous exposure to 2 mG (at 50 Hz in Europe) correlated to a 2.7-fold increase in childhood leukemia rate. See New Scientist, 31 Oct 92, p. 4.

msi

Magnetic Sciences International

HCR-2 • Box 850-295 • Tucson AZ 85735

Instructions for the Electric Field Sensor Unit

You can measure electric fields with the E-100 adapter. Your electric field sensor has three parts: the double banana plug adaptor and two sensor rods. Use only one rod at a time, depending on your need.

Use the short rod for most purposes, particularly in the house. First plug in the adapter, with the tab on the left. Then plug the short sensor in the right-hand jack (Fig. 1). (a jack is a plug hole). Hold the meter in your hand and let your thumb touch the screw which is in the lefthand jack of the adapter. This grounds the meter to your body and provides stable measurements.

You can use this sensor for approximate measurements of electric fields. It is compensated for the body's effect on the electric field you are measuring. This compensation is quite precise when the field source is overhead, such as from a power line. Inside a building, however, the electric field is a highly complex web of "lines" coming out from every live wire and electric device and curving toward the nearest grounded object, whether it be a metal chair, cabinet, pipe, or animal (including yourself). So the best use of the meter indoors is to get a general idea of the strength of the fields at selected spots, such as over the bed or at your favorite chair, and to identify sources, as the antenna generally points toward the source it is measuring. Always orient the meter so that you get the highest reading on the display.

Calibrating the meter: This step is to be done under or near an overhead power line of any kind. Plug the long sensor into the right-hand adapter jack (Fig. 2). Your meter is now set up to read the electric field strength in Volts per meter (V/m) at the 200m setting of the rotary switch. The other settings will read in kiloVolts per meter (kV/m). Turning the sensor will change the reading as you line it up with the electric field lines of force. When you get the highest reading, it is the correct reading, and the sensor will be pointing in the general direction of the source of the field. You are now ready to obtain a measurement which you can use for calibration of the short sensor.

Once the direction of the sensor has been established (usually straight up when under a power line) you must remove your body from proximity to the meter so as not to affect the accuracy of the reading. (Your body attracts the electric field, as you are an elevated grounding object. The field and current then flows through your body and near its surface affecting the meter in your hand).

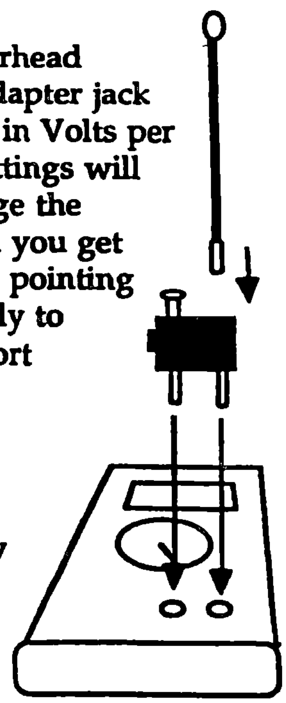


Fig. 1

To support the meter away from your body you may use a 4' length of plastic pipe or dry wood, with the meter secured to it by elastic. Note carefully some spot or pebble on the ground and take your reading directly over it. Support the meter at about waist height.

After recording the reading, remove the meter from the rod, replace the long sensor with the short sensor (in the same jack), and hold the meter in front of you and directly over the spot where you just measured, with your thumb on the grounding screw. Increase or decrease the distance between your body and the meter until you get approximately the same reading as you did when using the longer sensor. Note this position in front of your body and use it in the future. Also note the kind of footware you are using, and use the same shoes for future measurements. You have now calibrated the meter for hand-held use from overhead electric field sources. You can expect an accuracy of within 10% or 15% using the short sensor held by hand in this position. The sensor is designed to measure 60 Hz electric fields.

Inside a house you will find that the short sensor is more convenient to use in locating sources of electric fields. It will not give you as accurate a reading as outside, since the sources may not be overhead, but it can be used profitably as an indicator of relative strength and as a locator of live wires and individual sources.

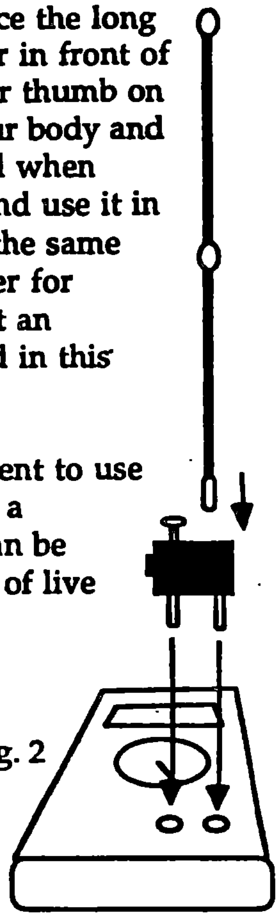
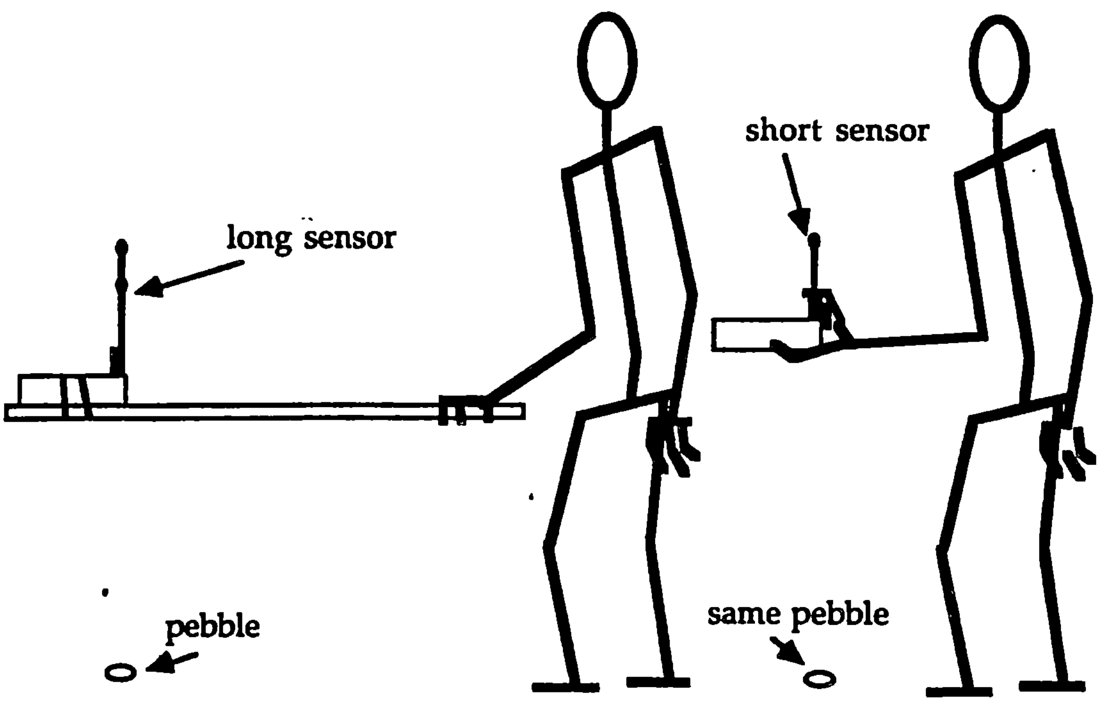


Fig. 2

power lines



FLUKE® Model 31 and 33 Current Masters™

True-RMS AC For Current Measurements You Can Trust

Electrical professionals today need current clamps that are up to the challenge of accurately measuring non-linear current loads–the kind generated by computers, adjustable speed drives, and some electronic ballasts. The Fluke 31 and 33 Current Masters™ combine true-rms ac current measurements with rugged, reliable performance for troubleshooting traditional and non-linear load problems.

Both the Model 31 and 33 measure rms ac current from 0.3 to 700A max. In addition, the Model 33 measures 1000A instantaneous peak.

33
31

Why True-RMS?

Average-sensing meters can produce readings that are 30% to 50% low when harmonics are present–but not the Fluke Current Masters Series. The Models 31 and 33 give **correct readings for any wave shape,** within the instrument's crest factor and bandwidth specifications.

Rugged and Easy to Use, with Comprehensive Features

Prying safely into tight spaces is easy with the Fluke 31 and 33. The angular jaw opening can handle 2 parallel 500 MCM cables, or a single cable, measuring 1½ inches in diameter. Heavy duty construction withstands job site abuse.

Clearly marked function modes and a digital display help eliminate operator error and the guesswork of interpreting readings. The analog bar graph provides a clear understanding of trends and surge currents. An audible beep confirms key presses, indicates new highs or lows detected while recording, and signals when exiting Min/Max or the manual range.

Fluke 31: *In addition to true-rms ac current measurement, the Fluke 31 offers a comprehensive feature set:* Combined **digital/analog** display; **frequency measurement** (Hz) to help detect harmonic currents in the neutral of a 3-phase system (it can also be used to determine the output frequency of an adjustable speed motor drive, or set the governor of an engine generator); **Display HOLD** to hold any reading for later viewing; multi-tone **Beeper** for audible feedback; **Auto and Manual Ranging; Sleep Mode** to extend battery life; **Hand Guard** to prevent accidental contact with conductors; a **Clip-On Holster,** and power-up self test.

Fluke 33: ***Use the Fluke 33 to perform more in-depth current evaluation and to record data.*** In addition to all the features of the Model 31, the Fluke 33 provides **MIN/MAX Record** to simultaneously record the maximum, minimum and average rms current or frequency values for over 24 hours–an advantage when measuring the starting current of motors, monitoring fluctuations in current or frequency, and determining the average over time. Additional features of the Fluke 33 include ***Smoothing™***, *and* ***Crest/Instantaneous Peak.***

LISTED UL 1244

ACCESSORIES

Included Accessories, Fluke 31 and 33 Current Masters™

The Fluke 31 and Fluke 33 come equipped with C30 Holster, Operator Manual, Quick Reference Guide, 9V battery (installed), and 1-Year Product Warranty

Optional Accessories

C30 Replacement Holster

Part #926993, Training Video: "Understanding Harmonics in Power Distribution Systems." Part #948513, Training Video: "Managing Harmonics in Power Distribution Systems."

(PAL format videos available through your local country distributor.)

Available through your local Fluke distributor or by calling 1-800-526-4731.

FEATURES	31	33
True-RMS AC Current Measurement (0.3-700A)	▼	▼
Digital/Analog Display	▼	▼
Frequency Measurement (0.5 Hz-10 kHz)	▼	▼
Display Hold	▼	▼
Auto and Manual Ranging	▼	▼
Crest/Instantaneous Peak	N/A	▼
Smoothing™	N/A	▼
MIN/MAX Record	N/A	▼
Safety Hand Guard	▼	▼
Beeper for Audible Feedback	▼	▼
Power-Up Self Test	▼	▼
Clip-On Holster	▼	▼

SPECIFICATIONS - FLUKE 31 and 33 CURRENT MASTERS™

Display Update: Analog Display 8 times/second Digital Display 2 times/second

Function	Range	Basic Accuracy	Resolution
RMS Current	0.3 to 700A 1000A peak	2%	0.01A on 40A range 0.1A on 400A range
Frequency	0.5 Hz to 10 kHz	0.2%	0.1 Hz < 1 kHz 1 Hz > 1 kHz
Instantaneous Peak **(33 only)**	0.4 to 600A 1000A max	3%	0.2A on 40A range 2A on 400A range
Crest Factor	up to 5.0		

Battery Life
80 hours typical (alkaline)

Size
9.11" L x 3.82" W x 1.73" D
(231.5 mm L x 97 mm W x 43.9 mm D)

Weight 17.6 oz (.5 kg)

One Year Warranty

ORDERING INFORMATION
Fluke 31 Current Clamp with Holster
Fluke 33 Current Clamp with Holster

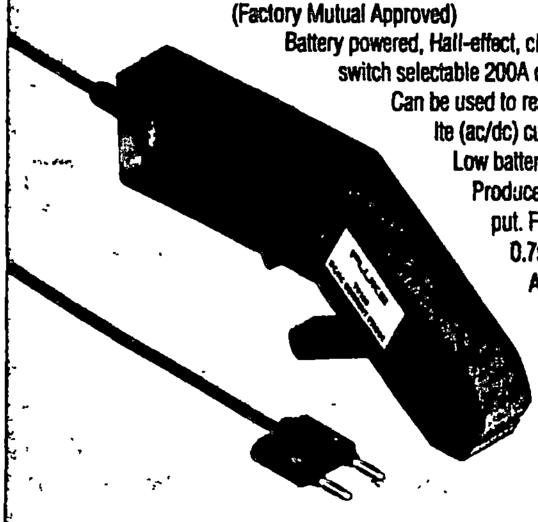
Bench/Portable Meters, and Digital Thermometers

CLAMP-ON AC/DC CURRENT PROBES

• Y8100 Clamp-On AC/DC Current Probe

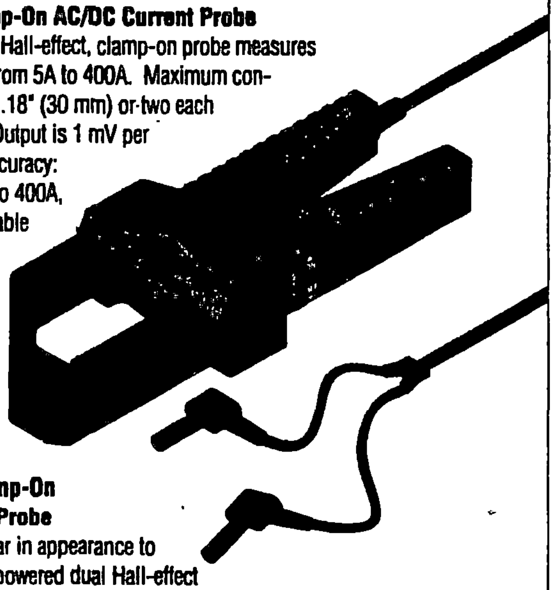
(Factory Mutual Approved)

Battery powered, Hall-effect, clamp-on probe with switch selectable 200A or 20A current range. Can be used to read dc, ac, or composite (ac/dc) current measurements. Low battery indicator light. Produces 2V full range output. For conductors to 0.75" (19 mm). Basic Accuracy: DC to 65 Hz: <100 A, ±2% of range ±0.7A; >100A-200A, ±3% of range ±0.7A.



• 80i-410 Clamp-On AC/DC Current Probe

Battery-powered, Hall-effect, clamp-on probe measures ac or dc current from 5A to 400A. Maximum conductor size: one 1.18" (30 mm) or two each 0.98" (25 mm). Output is 1 mV per amp dc or ac. Accuracy: ±(5%+2.5A), 5A to 400A, dc to 62 Hz. Useable to 400 Hz.



• 80i-1010 Clamp-On AC/DC Current Probe

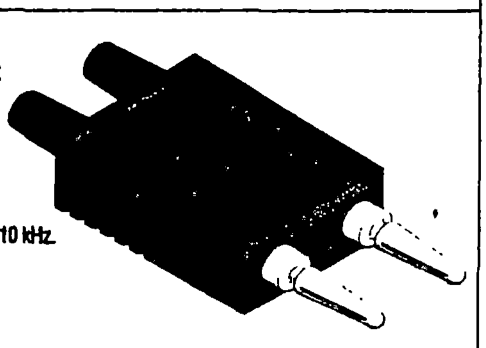
(Not shown-similar in appearance to 80i-410) Battery-powered dual Hall-effect clamp-on probe measures ac current to 700A, dc current to 1000A. Thumbwheel ZERO control compensates for residual core magnetism, improving the range of dc measurements down to 1A. Output is 1 mV per amp dc or ac. Maximum conductor size: one 1.18" (30 mm) or two each 0.98" (25 mm). Accuracy: ±(2% of reading +1A), 1A to 100A, dc to 62 Hz; ±3%, 100A to 700A, dc and 48 Hz to 62 Hz; ±5%, 700A to 1000A dc only. Useable to 440 Hz.

CURRENT SHUNTS

• 80J-10 Current Shunt

(Factory Mutual Approved)

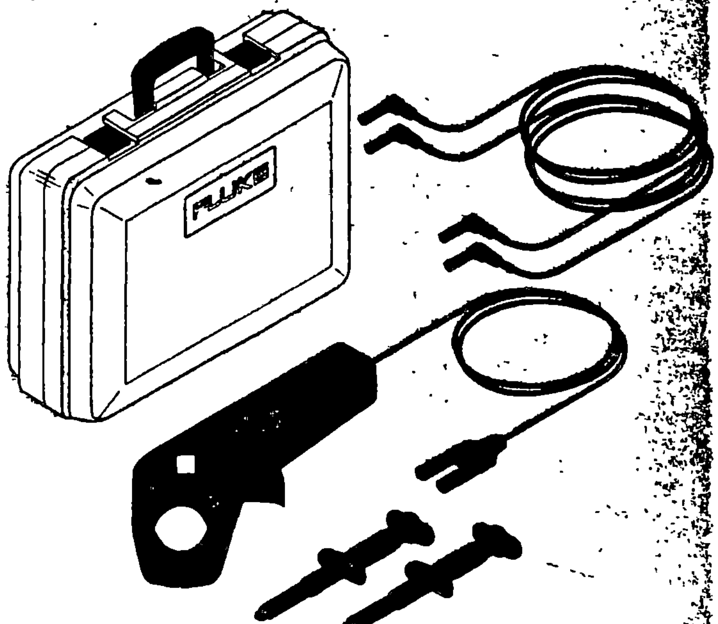
Allows measurement of ac or dc current with precision DMM (such as an 8060A). Will pass 10A continuously. Accuracy: ±0.25% from dc to 10 kHz.



CURRENT/POWER PROBES

• 80i-kW Current/(kW) Power Probe

The Fluke 80i-kW is a battery-powered clamp-on multimeter accessory that measures dc current, ac current, and true ac power (kW) without breaking the circuit. The 80i-kW uses special safety-shrouded voltage test leads with safety alligator clips to provide a voltage input that, in conjunction with the current input, gives a reading in kilowatts on the multimeter. Output to meter is 1 mV/Amp or 1 mV per kW. Frequency response of 3.2 kHz typical. Supplied with ruggedized hard carrying case, and AC20 Industrial Alligator Clips. Instructions included for 3-phase power measurements and power factor calculations.



SPECIFICATIONS

• DC CURRENT

Range: 1A to 1300A dc

Accuracy (± % of reading, 1 year):

1A to 700A	2% + 2A
700A to 1000A	3%
1000A to 1300A	4% typical

• AC CURRENT

Range: 1A to 1000A ac or ac+dc

Accuracy (± % of reading, 1 year):

	dc to 62 Hz	62 Hz to 440 Hz
1A to 500A	2% + 2A	6% + 2A
500A to 700A	3%	7%
700A to 1000A	6%	8% typical

• AC POWER

Range: 0.5-330 kW ac (90-660V ac, 1A to 500A ac)

Accuracy (± % of reading, 1 year):

48 to 62 Hz	390 to 410 Hz
3.5% + 0.5 kW	4% + 0.5 kW•
(power factor -0.5 to +0.5)	(power factor -0.9 to +0.9)

All Accessories have a full 1-Year warranty.

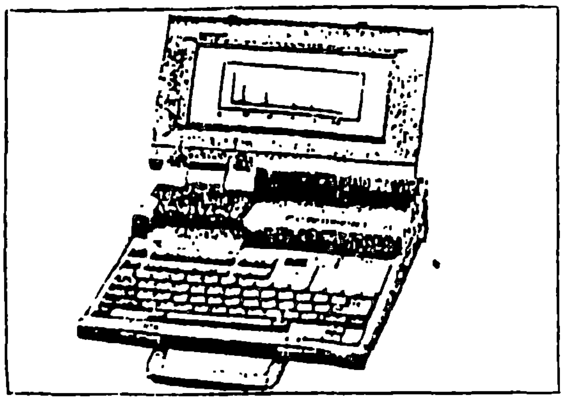
EXTREMELY LOW FREQUENCY (ELF) SPECTRUM ANALYZER

The portable, 17.5 x 27.5 x 32.5 cm analytical, battery-powered analyzer has a wide-range of applications including environmental monitoring. The 7.5 x 15 cm graphical liquid crystal display (LCD) screen comes with "soft keys". The analyzer displays waveform as well as Fourier frequency spectrum with 1% accuracy. An Intel 8031 microprocessor operates with a 4K RAM and 2k ROM memories. Also features: Burr-Brown OPA-128 "femtoamp" input, switchable 60 Hz notch filter, a reset button, display contrast adjustment. Ranges include 0.1 Hz to 10 Hz and 10 to 500 Hz. 256 data bins in display. Sampling frequency rate: 1000 Hz maximum.

The analyzer comes with a shielded 500,000 turn coil probe standard with a 15 meter cable for magnetic field measurements. Other electrical and mechanical probe transducers are available upon request.

Analyzer	**$ 4,589.00**

E.L.F. Laptop Spectrum Analyzer



Features:

* Displays signal and frequency spectrum
* Portable, fully IBM-compatible
* High resolution spectra
* Hard copy printout
* Extremely Low Frequencies up to 500 Hz

Specifications:

Range: 0-25 Hertz or 0-500 Hertz with anti-aliasing filters

Software: Menu-driven with help screen (free upgrades for one year)

Data Storage: Up to 108 sampled signals and spectra per disk

Computer: Sharp PC-4501 with one drive (720K), DOS 3.21

Printout: Star Micronic NX-1000 Printer and cable included

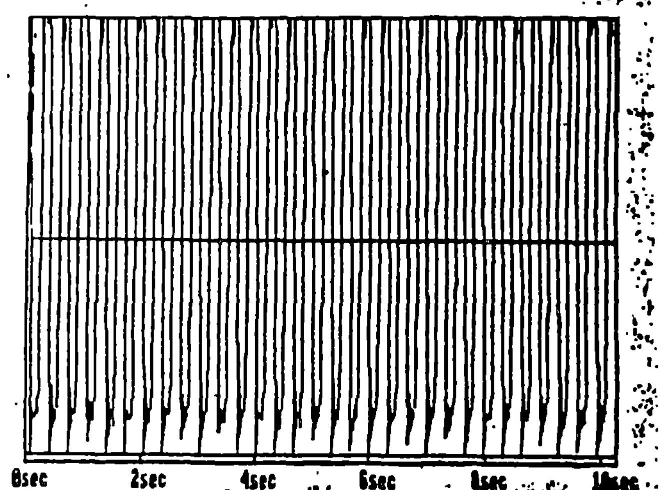
Memory: 256K expandable to 640K

Gain: continuously adjustable

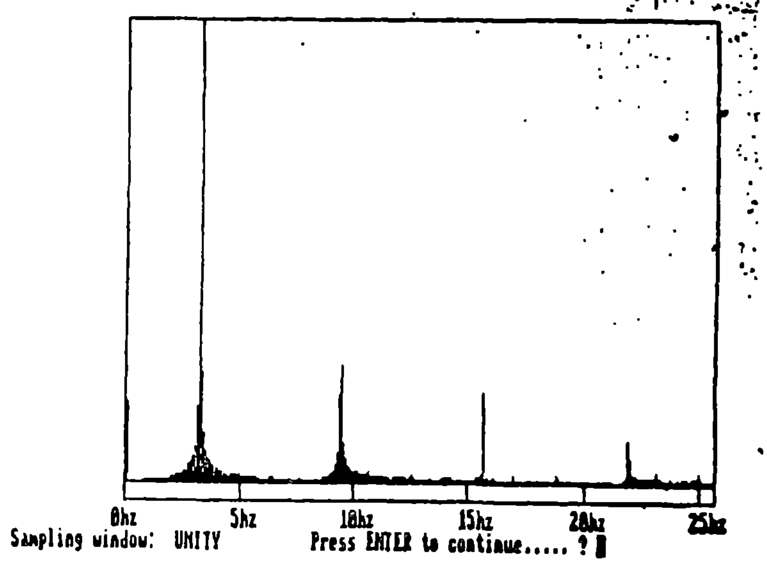
Input: 10 millivolts to 2.5 volts peak to peak, BNC connect

Resolution: 0.1 Hz in 25 Hz range; 2Hz in 500 Hz range

Hardware: internally mounted A/D interface board



IER-219 Laptop Spectrum Analyzer
IER-225 Carrying Case
IER-230 640K memory expansion



GEO-MAGNETOMETER BPM 2001

The **Geo-Magnetometer** measures static magnetic fields. The device's measurement ranges are: 0 - 100 nT, 0 - 1,000 nT, 0 - 5,000 nT, 0 - 10,000 nT, 0 - 50,000 nT, with an accuracy of 5% on any given scale value. Temperature does not affect the device (within customary tolerances). With the compensation feature, the measurement range extends between a freely-adjustable segment of 0 - 150,000 nano Teslas (or 1.5 Gauss). Any chosen range segment therein may be suppressed. Intensity changes as low as 0.01% may be detected on an analog gauge and even on a volume adjustable audio signal device. In other words, the detector objectifies static magnetic anomalies or disturbances according to pre-determined sensitivity scales.

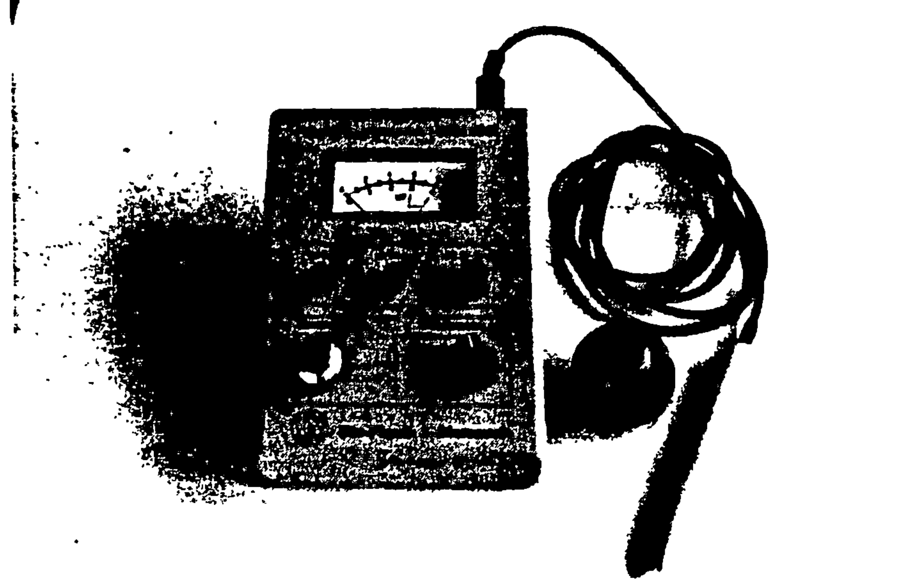
The **Geo-Magnetometer** comes with a probe attached to a 1.5 meter long cable. It is powered by four 1,5 Volt commercially available "mignon cell" batteries. The electrical current consumption is about 20 mA. The connector has an analog output of up to 1 Volt and a resistance of 5 kOhms.

The **Geo-Magnetometer** is designed to permit extremely accurate measurements over surfaces for the determination of variations in static magnetic fields over scale units as small as ten centimeter squares, the compilation of which can be logged and graphically displayed on the compatible **3D - Graphic - Computer BPM 3003.** The detector is useful for the measurement of magnetic anomalies over sleeping or working areas, appliances and artifacts.

The **Geo-Magnetometer** can serve as a diagnostic tool for agricultural field analyses, for the determination of geological formations, including fissures, faults, dislocations and subterrean water courses. It has been used as an aide in pre-design architecture and planning projects, real-estate value analysis, archaeological searhes and other investigations.

The 190 x 135 x 50 mm detector, with the probe, weighs 1 kg.. The 13 cm long cylindrical probe has a diameter of 2 cm.

The devices comes with a one year manufacturer's warranty for service and parts.



3D - GRAPHIC - COMPUTER BPM 3003

This easy-to-use system prints out the graphic of the computed results of the logging of results detected with the **Geo-Magnetometer BPM 2001**. It permits an accurate "on-site" visualization of static magnetic field anomalies or "disturbances", within five minutes of a survey. The software and hardware are fully integrated and permit the printed display of front views, back views, whole three-dimensional graphics or single or combination line(s) of measurement.

The computer can work on either 110 V or 220V input and consumes about 50 Watts. The signal input has a one channel analog input with an 8 byte analog/digital converter. The input voltage is set with a range going from 0 - 1 V, with a resistance greater than 1 MOhm. The A/D converter computes 100 measurements per second. The entire computer is grounded to the case and onto the power supply.

The Computer has a parts warranty which does not cover transportation costs to the manufacturer.

BPM 3003 **$ 7,650**