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THE DESIGN OF A MINIATURE PERSONAL EXPOSURE MONITOR FOR CONTINUOUS REAL-TIME DATA ACQUISITION IN ELECTROMAGNETIC FIELD EXPOSURE ASSESSMENT

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ABSTRACT

THE DESIGN OF A MINIATURE PERSONAL EXPOSURE MONITOR FOR CONTINUOUS REAL-TIME DATA ACQUISITION IN ELECTROMAGNETIC FIELD EXPOSURE ASSESSMENT. Norman H. Hansen*, Thomas J. Conroy* and Bary W. Wilson. Pacific Northwest Laboratory, Richland, WA 99352

The design of a small, light-weight personal exposure monitor suitable for use in EMF exposure assessment studies is nearing completion at Pacific Northwest Laboratory. The monitor is designed to be non-obtrusive, battery operated, and able to continuously record extremely low-frequency (ELF) (10hz-500hz) magnetic-field data. It also captures high-frequency (500hz - 10Mhz) transients that exceed a preset threshold, retaining the largest transients in memory. The monitor can record one or more days of data on a single easily replaceable, credit-card-size memory (PCMCIA). A battery charge will last a minimum of one day. Batteries are rechargeable and easily replaced. A data-compression algorithm is under development that will be tailored to the efficient compression of low-frequency EMF signals and will permit data to be logged for at least one day before swapping memory cards. The memory cards are readable by a base-station computer that can perform analysis of the data. The monitor is designed to accommodate four inputs supporting full-field sensors as well as a proposed ocular exposure measurement system. Our design effort has shown that a practical personal exposure monitor for EMF can be built based on current technology, continuous logging of real-time ELF waveforms is both feasible and practical, and such a device is appropriate for proposed EMF exposure studies.

INTRODUCTION

The Miniature Personal Exposure Monitor (MiniPEM) for magnetic fields is being developed to allow improved EMF exposure assessments in support of epidemiologic studies. The design effort has focused on achieving small size, low weight, and a minimum of 24 hours of operation between battery recharges and memory card change-outs. Special emphasis has been placed on providing functionality appropriate for exposure assessment studies.

Prior research performed at Pacific Northwest Laboratory illustrated the importance of monitoring both extremely low-frequency magnetic fields and high-frequency magnetic field transients. The most challenging aspect of this design has been to address the high-frequency acquisition, because of the requirements this places upon processor resources, especially memory. One day of continuously sampling (f_{sample} = 20Mhz) high-frequency magnetic fields with a full-field probe generates as much as 3.5 trillion (10^{12}) bytes of data. This exceeds the memory capacity of most super computers, let alone the memory capacity possible in a small hand-held device.

To overcome this problem, we have adopted separate approaches for sampling in the low- and the high-frequency portions of the magnetic spectrum. The extremely low-frequency (ELF) (10hz-500hz) signal content is continuously sampled, compressed, and stored to memory whenever its magnitude is greater than a preset threshold (nominally 100mGauss/second). The high-frequency (500hz-10Mhz) content is dominated by transients. Thus, the recommended approach is to perform high-frequency transient capture, keeping a count of all transients exceeding a preset threshold (nominally 1 Gauss/second) and saving in memory the "n" worst transients.

The MiniPEM will provide researchers with a rich data set including continuously sampled ELF waveforms, transient counts and detailed waveforms for the worst-case transients. As more is learned about what actually constitutes "dose," more statistical analysis capability will be added to the MiniPEM permitting researchers to extract the most pertinent information.

THE CASE FOR PERSONAL DOSIMETERS THAT RETAIN MAGNETIC FIELD SPECTRAL INFORMATION

There is increasing interest in the possibility that transients and higher frequency components may be important in determining the "dose" associated with the biological effects observed as a result of exposure to magnetic fields. To some extent, this interest is based on results from EMF epidemiologic studies, and on the fact that the magnitude of the induced electrical field in biological tissue increases with the frequency of the time-varying magnetic field.

Transient fields and those with high-frequency components are associated more closely with proximity to end-use electrical devices than with power lines per se. It is often proximity to end-use electrical devices that is associated with increased risk in both occupational and residential epidemiologic studies on EMF.

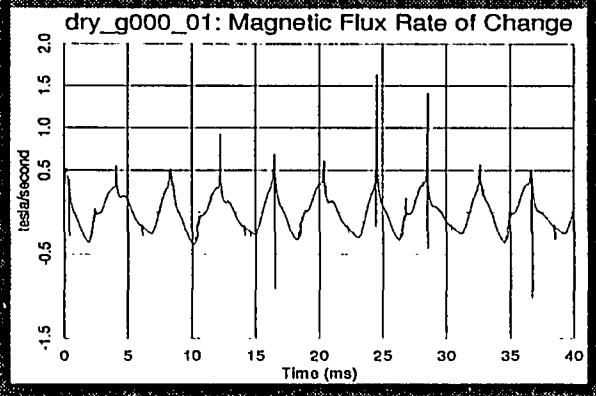
Based on these considerations, characterization of the spectral content of magnetic fields has become of increasing importance in the effort to determine what constitutes "dose" in epidemiologic studies. MiniPEM constitutes a first attempt at determination of spectral content with a lightweight personal dosimeter. Spectral content is characterized by measuring the field in the 10-500hz range continuously, and by making provisions to identify and characterize higher-frequency transient events.

Presently available personal dosimeters such as the EMDEX II do not allow continuous monitoring of the magnetic field. Hence, spectral information is not available from these devices.

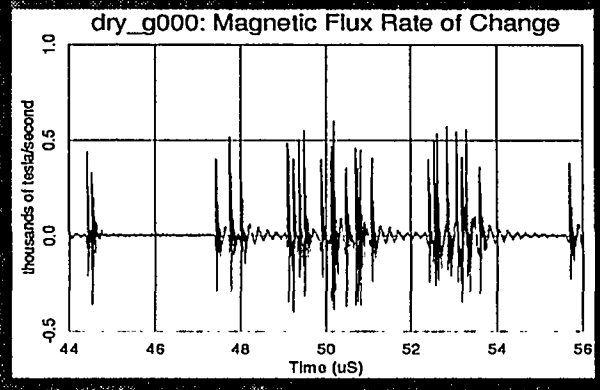
We intend that the MiniPEM prototype should be the first in a family of lightweight personal exposure meters that will support the next generation of EMF epidemiologic studies.

MAGNETIC FIELD TRANSIENTS

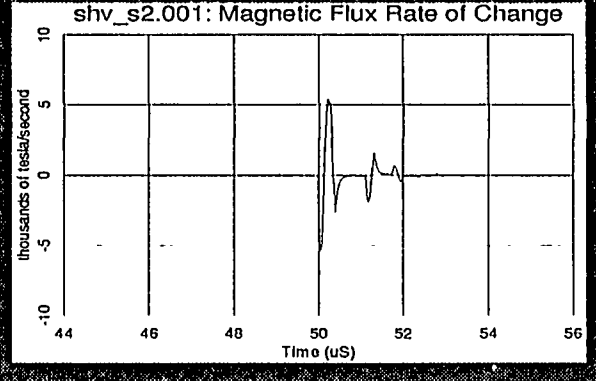
Transient Waveforms from Appliances



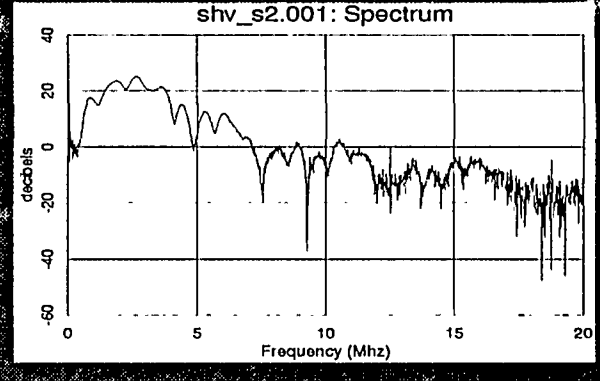
a) Blow dryer (low frequency)



b) Blow dryer (high frequency)



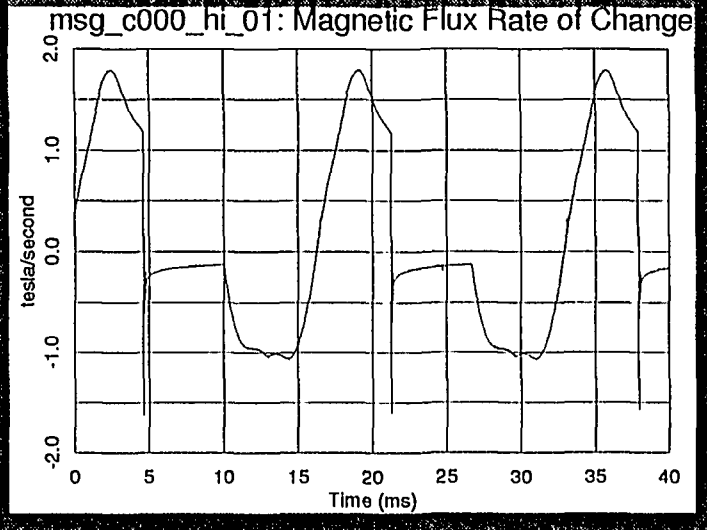
c) Electric shaver (time series)



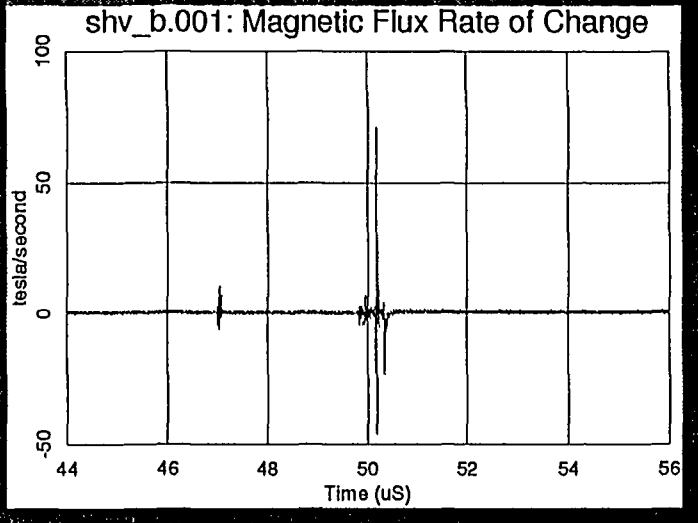
d) Electric shaver (spectrum)

MAGNETIC FIELD TRANSIENTS

Transient Waveforms from Appliances

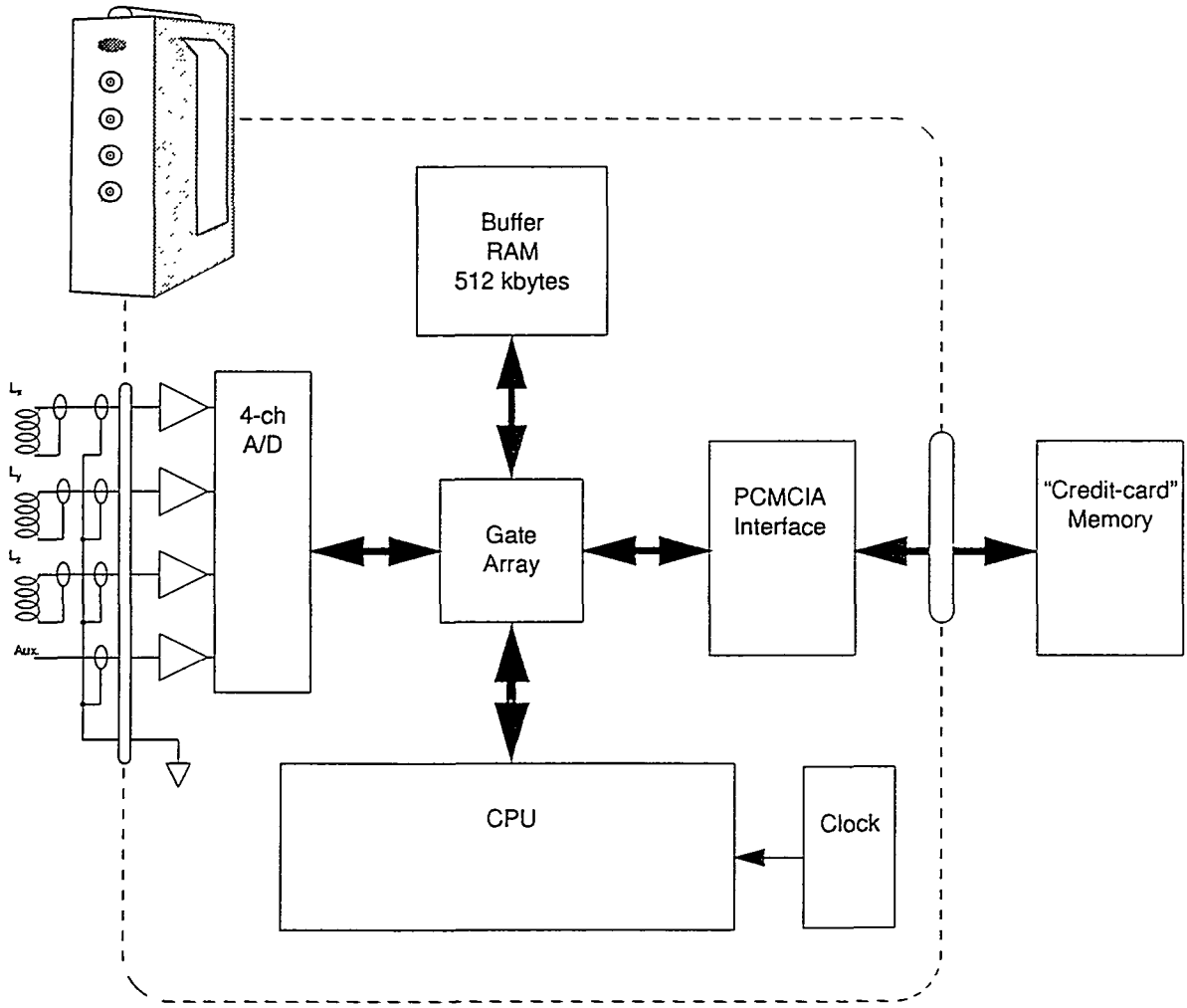


e) Personal massage unit

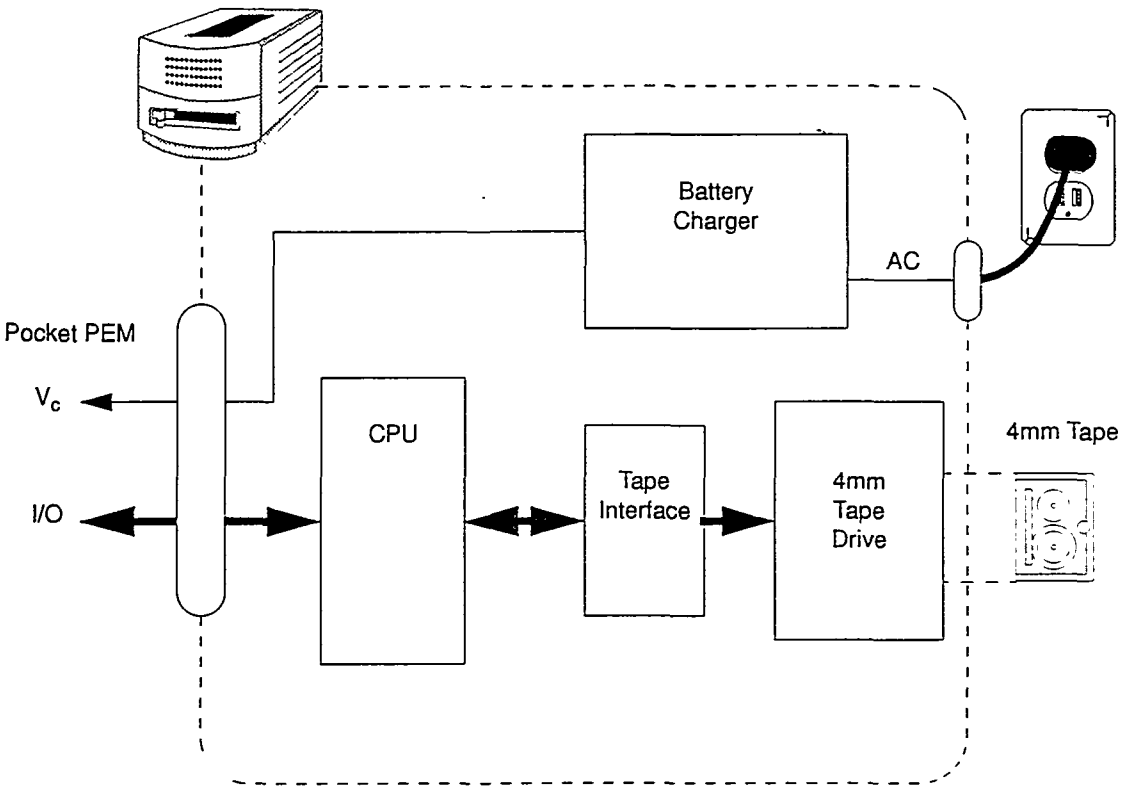


f) Electric shaver

PERSONAL EXPOSURE MONITOR

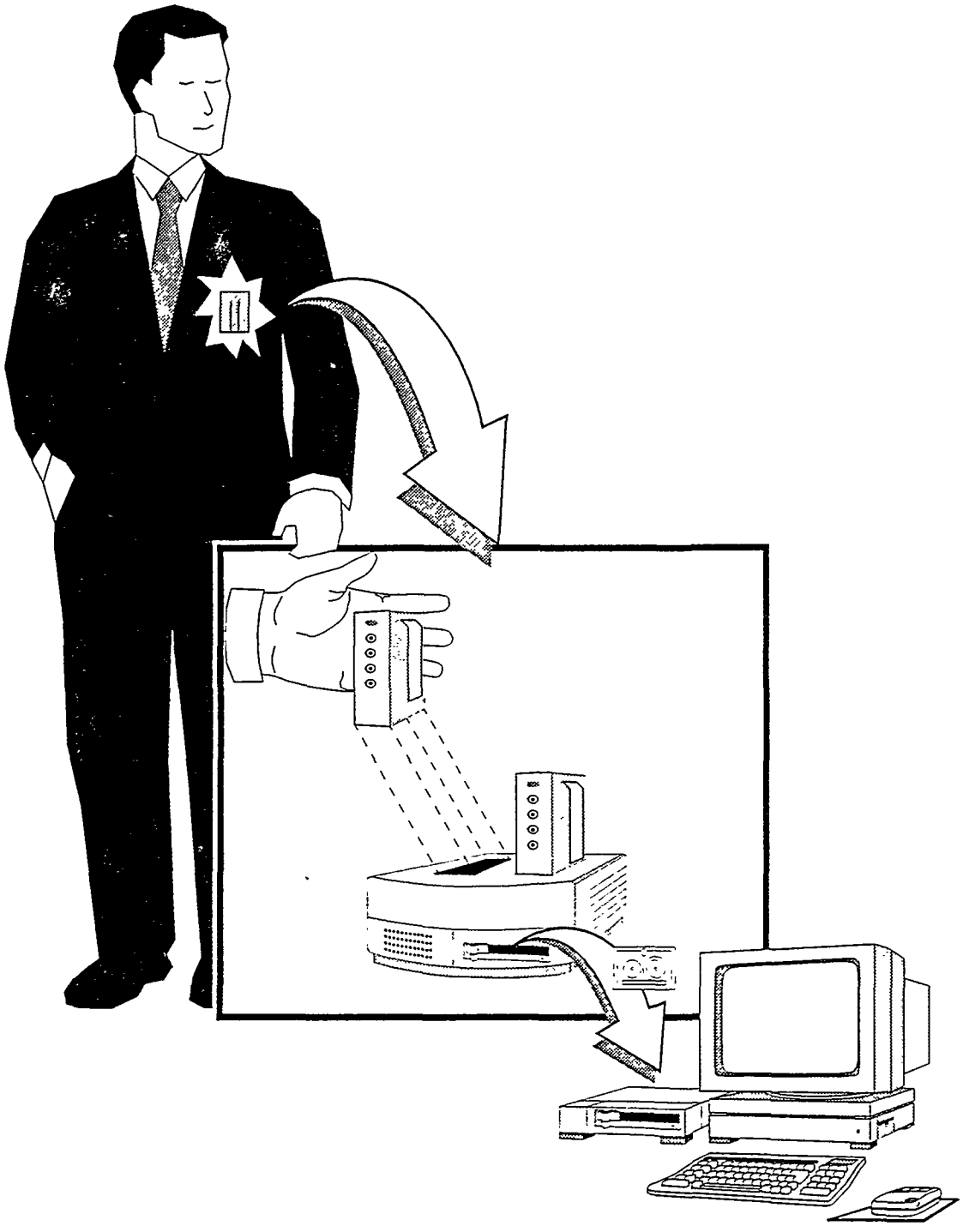


Block Diagram - Miniature Personal Exposure Monitor.



Conceptual Diagram - Recharger/Mass Storage Unit.

PERSONAL EXPOSURE MONITOR



Conceptual Diagram - MiniPEM, Receptacle and Data-Analysis Base Station

PRELIMINARY SPECIFICATIONS

Notice: The following specifications are preliminary and apply to the prototype model. Refinements planned for the production model are expected to reduce the physical size and extend both the battery life and memory capacity.

PHYSICAL

Dimensions: 14cm x 5.7cm x 3.8cm
Weight: 0.7kg

ELECTRICAL

Battery Life: 24 hrs
Inputs: 4 channels: 3 coil inputs / 1 auxiliary input
Bandwidth: Low frequency: 10hz to 500hz
High frequency: 500hz to 10Mhz
Sampling rate: Low frequency: 1khz
High frequency: 20Mhz

FUNCTIONAL

Modes: **ELF acquisition:** Continuous digitization, compression and storage of 10hz to 500hz magnetic waveforms.
Transient capture: Digitization, compression and storage of transients with frequency components ranging from 500hz to 20Mhz and magnitudes exceeding a preset threshold window. A count of transients exceeding the threshold and the "n" largest transients are retained.

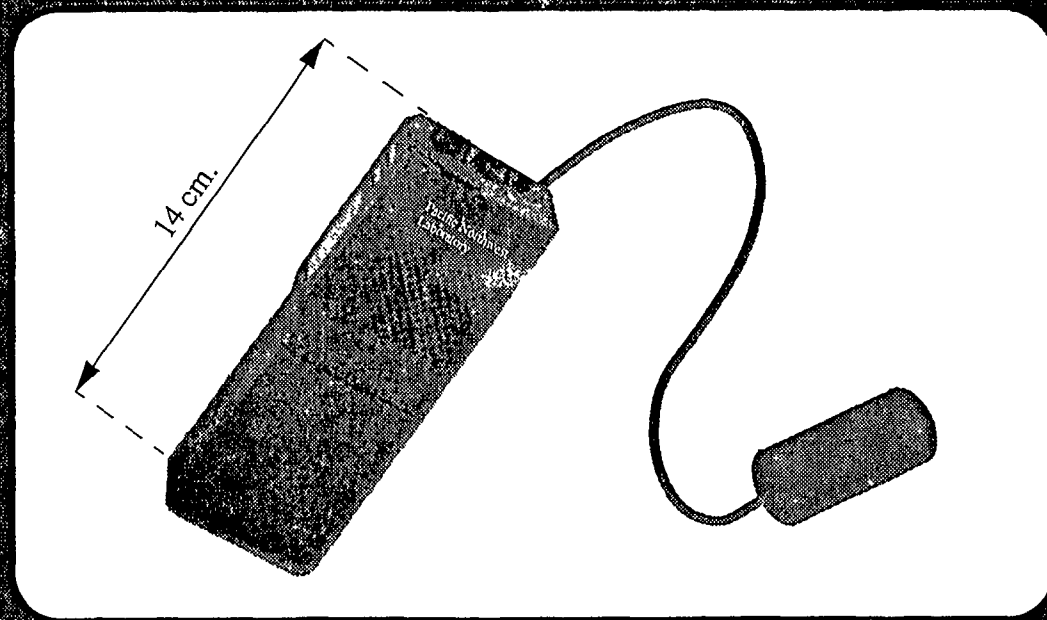
Auto-ranging: The best of four possible input ranges is automatically selected for each input channel. The system achieves a resolution of 0.01 mT/S on the lowest range setting and a full-scale value of 10,000 T/S on the highest range setting.

Capacity: Dependent upon memory size and field activity. Typically one day of waveforms can be stored before swapping memory cards.

MINIATURE PERSONAL EXPOSURE MONITOR

Prototype Configuration

- The enclosure, mounting hardware, battery and recharger will come from a small commercially available portable radio.
- The electronics will include a PCMCIA memory card for storing waveforms.
- The remaining electronics will be custom designed.



CONCLUSIONS

- Spectral content may be significant in the determination of what constitutes "dose". Hence, personal dosimeters should retain spectral content in captured waveform data.

- The design and implementation of a personal dosimeter that continuously digitizes and records ELF magnetic fields and captures the "n" worst transients is both feasible and practical.

- Such a device can be made small, lightweight, and battery-operated for use in epidemiologic studies.

- The dosimeter is capable of storing 24 hours of data between battery recharges and memory-card change-outs.

FUTURE WORK

- An algorithm tailored to the compression of EMF waveforms will be completed and demonstrated. This will significantly improve memory utilization and increase the time between memory change-outs.

- The electronics will be further down-sized. The desired goal is to have a MiniPEM the size of a small pocket pager.

- Keeping pace with new developments in electronics, the MiniPEM will be enhanced for operation at higher frequencies and for longer periods of unattended data acquisition.