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Two Systems for Collection, Storage, and Analysis of Measurements Made with RF Field Survey Instruments

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The American Conference of Governmental Industrial Hygienists, the American National Standards Institute, and the Occupational Safety and Health Administration limits for workers exposed to radiofrequency (RF) radiation specify a time-weighted average over any 6-minute period within the workday. Researchers at the National Institute for Occupational Safety and Health are conducting epidemiologic studies of male and female workers exposed to RF radiation at or near a frequency of 27.12 MHz. These studies require the characterization of the workers' exposure to RF radiation. Exposure data need to be collected over at least 6-minute periods and analyzed to make valid comparisons with present and past exposure standards. Field survey instruments used to measure RF radiation in the near field usually have a volt meter-type output, e.g., 1 volt is a full scale reading. These instruments can record a single maximum reading during a measurement period, but they are not capable of repeated data storage over time to give a 6-minute average exposure. To store survey data over selected time periods, two different data loggers were interfaced with the RF survey instruments. The data loggers were interfaced with MS-DOS™ microcomputers using proprietary and in-house software to allow for subsequent analysis of the stored survey data. Using this system, max/min, average, cumulative, and histogram plots were generated for selected 6-minute periods. If more sophisticated analyses are necessary, these data can be transferred to a larger statistical analysis software package. Each data logger has advantages and disadvantages for measurement of RF radiation from industrial sources. Electromagnetic interference, sampling frequencies, data representation and accessibility, and cost factors must be weighed against the intended use of the data logger. **Cox, C.; Grajewski, B.A.; Edwards, R.M.; Murray, W.E.; Conover, D.L.: Two Systems for Collection, Storage, and Analysis of Measurements Made with RF Field Survey Instruments. Appl. Ind. Hyg. 4:286–290; 1989.**

Introduction

Radiofrequency (RF) radiation refers to a nonionizing portion of the electromagnetic spectrum in the frequency range of 0 Hz to 3000 GHz. Applications include power transmission, radar, radio, television, satellite communication, microwave oven, medical diathermy, and industrial sealing and welding. The average person is exposed to extremely low levels of RF radiation from the natural thermal radiation of the environment and the earth's atmospheric resonant fields.[1] Most other sources of RF radiation are artificially created, and, consequently, approximately 9 million workers may be occupationally exposed to levels far higher than natural levels of RF radiation.[2]

Researchers at the National Institute for Occupational Safety and Health (NIOSH) are presently conducting epidemiologic studies of male and female RF heat sealer operators exposed to 27.12 MHz radiation. To perform a comprehensive exposure characterization for these operators, an adequate system for collection, storage, and analysis of RF radiation field measurements must be used.

Background

Measurement of RF radiation in workplace settings requires a survey instrument that is hand portable, rugged, and operational in high RF radiation fields (over 560,000 $[V/m]^2$). Industrial levels of RF radiation may cause significant electromagnetic interference (EMI) with survey instrumentation adequate for many other applications. Further, exposure data need to be collected over at least 6-minute periods and analyzed in order to make valid comparisons with current exposure standards. A data logger which meets these general requirements is a valuable accessory to the RF survey meter if continuous readings, which can be averaged, are preferable to one maximum survey reading. This is the case when characterizing worker exposure to RF radiation.

The Occupational Safety and Health Administration (OSHA),[3] the American Conference of Governmental Industrial Hygienists (ACGIH),[4] or the American National Standards Institute (ANSI)[5] occupational exposure limits are used as criteria in the evaluation of RF exposure in the workplace. A significant aspect of these

The use of company or trade names is for identification only and does not imply endorsement by the National Institute for Occupational Safety and Health.

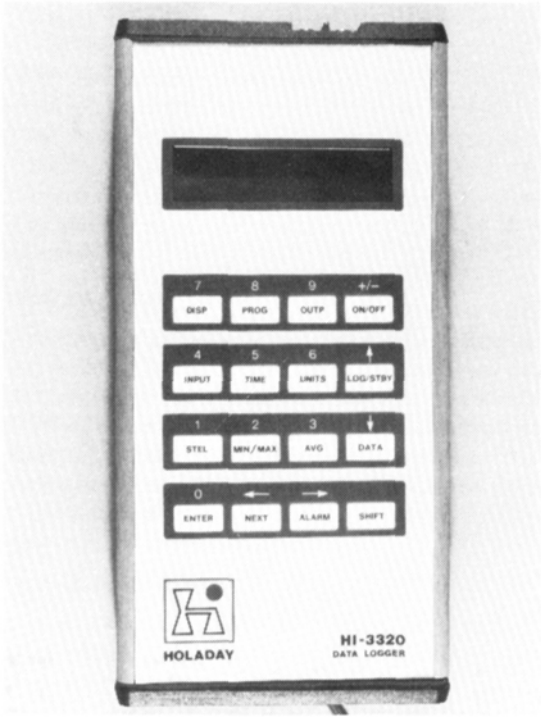

FIGURE 1. Holaday HI-3320 data logger.

standards is that the exposures must be averaged over *any* 6-minute period. If the exposure level exceeds the standard for any 6-minute period within the workday, the exposure exceeds the time-weighted-average exposure limitations of the standard. To determine with absolute certainty that workers are not overexposed, all 6-minute time periods within the work day must be evaluated. For example, if an exposure measurement was made every second, an 8-hour workday would require saving 28,440 different 6-minute time periods. Although appropriate sampling strategies may be used to reduce the number of measurements needed, RF survey instruments presently available are capable of retaining only the maximum reading during a sampling session. The number of recordings required and the lack of an averaging feature preclude the use of manual recording methods.

Since many RF heat sealing sources in our studies had on-times of 1–3 seconds, a method was needed to record measurements at least once per second for a minimum of 6 minutes, i.e., 360 recorded measurements in each 6-minute period. The introduction of small, portable microprocessor-based data loggers makes continuous recording of measurements feasible for preset time periods of 1 second or less.[6] These recordings can be retrieved and uploaded for subsequent review and analysis.

After reviewing the technical specifications for several data loggers, two data loggers judged to be most suitable for use were selected. The Holaday HI-3320 (distributed by Holaday Industries, Inc., Eden Prairie, Minnesota; manufactured by Metrosonics, Inc., Rochester, New York) (Figure 1) and the Gulton® RR-400 Rustrak® Ranger™ (Gulton Industries, Inc., East Greenwich, Rhode Island) (Figure 2) were evaluated. The purpose of this evaluation was to determine the suitability of these data loggers for use in a very specialized area of field surveying, RF radiation measurements; however, these determinations may not be relevant to other data logging applications.

Survey Equipment and Methodology

The Holaday HI-3320 data logger was specifically designed and manufactured for use in RF radiation fields. The Gulton RR-400 Rustrak Ranger is a general use data logger not designed for use in RF radiation fields. The RF survey equipment consisted of a Holaday HI-3003 Broadband RF Exposure Meter with an STH-03 H-field probe and an STE-03 E-field probe interfaced with one of the two selected data loggers.

Since the Holaday RF survey meter is a 1-volt, full-scale instrument, the data loggers were programmed for a scale of 0–10, with 10 equaling a full-scale reading of 1 volt. Each data logger has 8k of memory to store the RF measurements prior to uploading to a MS-DOS™ (Microsoft® Corporation, Redmond, Washington) microcomputer. A QuickBASIC 4.0[7] (Microsoft Corporation, Redmond, Washington) program was written to upload from the Holaday HI-3320; uploading from the Gulton RR-400 Rustrak Ranger was accomplished with proprietary software (Pronto version 2.10) which is included as part of the Ranger package.

The Holaday HI-3320 data logger provides a sample distribution and a minimum, average, and maximum value (Figure 3). The Rustrak Pronto software program can provide simple descriptive graphs of the data and can calculate some basic statistical parameters such as maximum, minimum, average, and cumulative values. A printer output of a typical graph is shown in Figure 4. The quality of the graph is limited by the Pronto software which only supports dot-matrix printers. If additional statistical analyses were required, the data files were transferred in American Standard Computer for Information Interchange (ASCII) format to a SAS®-Personal Computer (SAS®-PC) version 6.02 software package (SAS Institute, Inc., Cary, North Carolina).

Evaluation of Data Loggers

Each of the two data loggers were evaluated independently for use in a very specialized area of field surveying, RF radiation measurements. Some of the problems encountered with each data logger could be resolved, while others could not. Our assessment of these problems and advantages/disadvantages for each data logger are discussed below and summarized in Table I.

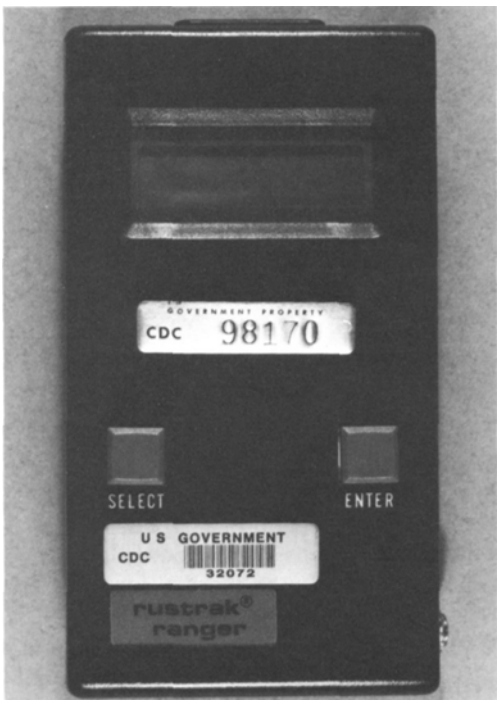

FIGURE 2. Gulton RR-400 Rustrak Ranger data logger.

```
HOLADAY HI-3320 SN 1035 V2.3  3/86

CURRENT DATE:  3/12/87
CURRENT TIME: 11:10:01

CALIBRATION
 0.0000    V =  0.0000 07fsu2
 0.1000    V =  0.1000 07fsu2

LOWER ALARM:  0.0000 07fsu2
UPPER ALARM:  0.0000 07fsu2

UNITS: fsu2

INPUT READS: 0.0443 07fsu2
TEST STARTING DATE:   3/12/87
TEST STARTING TIME:  11:04:51
 ELAPSED TIME:  0 DAYS  0:02:29
OVERALL AVG:  0.2555 07fsu2
OVERALL MIN:  0.0006 07fsu2
MIN OCCURRED  3/12/87 @ 11:08:09
OVERALL MAX:  0.6533 07fsu2
MAX OCCURRED  3/12/87 @ 11:08:01
    NO STEL     PERIOD FINISHED

 TIME HISTORY
PERIOD LENGTH:  0:00:01
# OF PERIODS  COMBINED:   1

    MIN          AVG          MAX

DATE:  3/12/87  TIME: 11:06:19  TAG #:    2
  0.0330 07  0.0368 07  0.0482 07  -*
  0.0644 07  0.0968 07  0.1130 07    - *+
  0.1130 07  0.1687 07  0.2201 07       -   *  +
  0.2527 07  0.2930 07  0.3336 07              - * +
  0.3650 07  0.3852 07  0.4030 07                   -* +
  0.4038 07  0.4121 07  0.4216 07                      *+
  0.4006 07  0.4083 07  0.4193 07                     -*+
  0.3990 07  0.4025 07  0.4056 07                     -*
  0.3970 07  0.4041 07  0.4114 07                     -*
  0.3603 07  0.3723 07  0.3851 07                   -*
  0.3176 07  0.3353 07  0.3540 07                 -* +
  0.2904 07  0.2974 07  0.3127 07                *+
  0.2396 07  0.2536 07  0.2805 07             -*+
  0.2056 07  0.2140 07  0.2353 07           * +
  0.1454 07  0.1690 07  0.1951 07         - *+
  0.1130 07  0.1305 07  0.1444 07       -*+
  0.0805 07  0.0990 07  0.1127 07     -*+
  0.0615 07  0.0751 07  0.0806 07    -*
  0.0430 07  0.0473 07  0.0536 07   *+
  0.0443 07  0.0540 07  0.0727 07   -*+
```

FIGURE 3. Holaday data logger output of RF electric field measurements with a time history of minimum (−), average (*), and maximum (+) values in field strength units squared (fsu^2). An amplitude (frequency) distribution of data values is also included in the "All Formatted" report form.

What were assessed as problems, advantages, and/or disadvantages may or may not be critical in other applications.

Holaday HI-3320 Data Logger

Cables

Cable ends (phono jacks or BNC connectors) for connecting the data logger to the survey meter differ depending on when the survey meter was manufactured. Holaday does not offer cables to connect the data logger to microcomputers. Cables were purchased from Holaday to connect the data logger to the survey meter. The cables to connect the microcomputers to the data loggers were made from commercially available electronic parts.

Electromagnetic Interference (EMI)

Concern was expressed that the high RF electric fields [greater than 10^5 $(V/m)^2$] would interfere with the operation of the data logger system during the field surveys. The RF survey meter/data logger system was tested in 10 MHz RF electric fields up to 560,000 $(V/m)^2$ in a Narda Model 8802 transverse electromagnetic (TEM) transmission cell without detectable EMI effects. In addition, the RF field survey meter readings [$\leq$ 120,000 $(V/m)^2$ and $\leq$ 15 $(A/m)^2$ at 0.1–30 MHz] were compared to the data logger display value with no noticeable difference.

Data Sampling and Storage

The manner in which survey measurements are logged and stored in the HI-3320 is fixed and cannot be changed, which created problems for our specific application. The sampling rate is limited to 1 or 4 times per second only. Since many of the RF sources in our studies only remain on for 1 second or less, the option of selecting a sampling rate of 1, 2, 4, 8, and 16 times per second

would be preferred. Survey measurements are logged in a set ASCII format, but when logging at a sampling rate of 4 times per second, only the minimum, maximum, and average values during each second are stored in memory. All four measurements sampled during each second are effectively lost to further statistical analysis. Finally, a raw data file suitable for additional statistical analysis is not provided, but must be generated by removing extraneous identification and summary information from the ASCII-formatted file.

Uncontrolled Front Panel Lockout

Uncontrolled front panel lockout was experienced during normal operation, resulting in loss of data and a nonfunctional data logger. It was suspected that the lockout was due to a low battery although a low battery message had not been observed. On the advice and direction of a Metrosonics service technician, the leads to a capacitor at the rear of the data logger's mother board were shorted, and then a new battery was installed. This restored the data logger to normal operation.

Uploading to Microcomputers

Holaday does not offer a software package for interfacing the data logger with microcomputers. A QuickBASIC 4.0 program was written for uploading stored data, storing the data to disk, reviewing the stored disk files, graphing the data from disk files, and printing data files and graphs. Alternative solutions to this problem are to use generic telecommunications software or commercially available software compatible with the Holaday data logger, e.g., the package offered by Metrosonics.

Advantages/Disadvantages

The following features of the Holaday HI-3320 are considered advantages.

1. The data logger is adequately shielded against EMI.
2. The sampling rate may be increased to a maximum of 4 times per second.
3. Connecting cables are available for several RF survey meter models.
4. MS-DOS software is available for uploading data to microcomputers.
5. The survey data is stored in ASCII format which allows the survey data to be transferred to statistical programs for further analysis.

These features were considered disadvantages:

TABLE 1. Selected Features of the Two Data Loggers

Feature	Holaday HI-3320	Rustrak Ranger
Size	18.3 × 9.1 × 3.0 cm	14.5 × 8.0 × 3.0 cm
Weight	590 g	260 g
EMI shielding	Yes	No
Sampling period	0.25 to 1.0 s or greater	0.65 s
Upload software	Write or purchase	Included with data logger
Preliminary analysis software	Write or purchase	Included with data logger
Storage of survey data: file type	ASCII	Machine language, convertible with provided software to ASCII
Clean raw data file available	No	Yes
Cables: RF meter to data logger	Order from Holaday	Fabricate
Cables: data logger to microcomputer	Fabricate	Included with data logger
Cost	Relatively expensive (> $1600)	Relatively inexpensive (> $500)

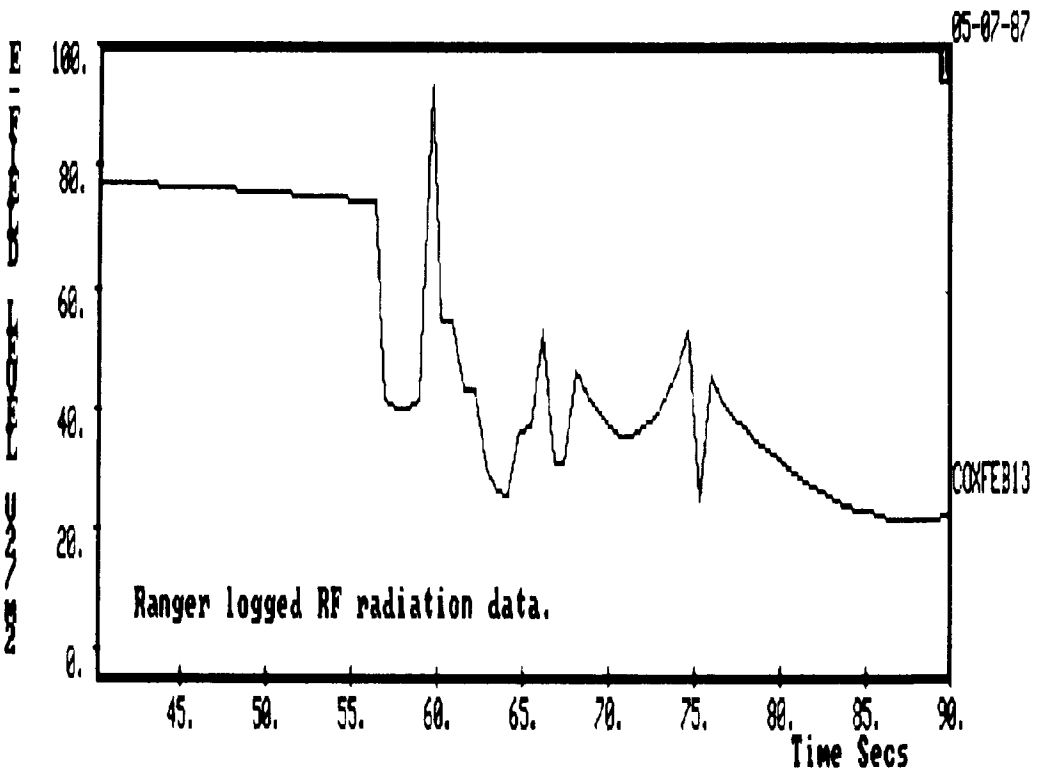

FIGURE 4. Ranger data logger graph of RF electric field measurements.

1. Sampling rates limited to 1 or 4 times per second, at a rate of 4 times per second, and individual readings are not retained in storage.
2. Although stored in ASCII format, the data files contain information which must be removed before being transferred to statistical analysis programs.
3. The data logger can only handle a voltage input.
4. An undetected low battery condition can shut down the data logger and destroy logged data.
5. The HI-3320 is relatively expensive.

Gulton RR-400 Rustrak Ranger Data Logger

Cables

Cables (with phono jacks or BNC connectors) to connect the Ranger to RF survey meters are not standard and are not available from Gulton. Using commercially available electronic parts, the necessary cables were fabricated in less than two hours. Cables to connect the data logger to microcomputers are provided.

Electromagnetic Interference (EMI)

The Ranger data logger/survey meter system was tested for EMI using the same methods as for the Holaday. Since the Ranger is not shielded against RF radiation, it was no surprise when interference was experienced when logging in RF fields which were greater than 10,000 $(V/m)^2$.

It was determined that the Ranger could be shielded from EMI by placing it in a copper mesh screen bag and encasing the connecting cable in a copper mesh tube. Although a Ranger shielded in this fashion logged data without EMI effects in our RF test cell, the data logger was harder to operate in a copper mesh bag; the program buttons were not easy to operate, and the digital readouts were difficult to see.

Data Sampling and Storage

The minimum sampling period for the Ranger is 0.65 second, and it cannot be changed. This sampling period, although relatively short for many other applications, does not allow an adequate characterization of RF sources with on-times of one second or less.

In contrast to the Holaday data logger, which stores each data point as an average of four readings per second at its highest sampling rate, the Rustrak samples at 0.65-second intervals and stores the data as read by the survey instrument or according to an algorithm. Incoming data are compared to a set of internally stored patterns. If the data can be represented by one of these patterns, they are stored as such. Thus, the "raw data" file generated will contain pattern-interpolated values not present in the original survey readings. The storage decisions made by the Rustrak are not accessible; therefore, the real data values cannot be distinguished from data values fitted by one or more algorithms.

Data Analysis

A software package is provided for uploading, graphing, and exporting the Rustrak data. The graphics component also generates several simple statistics, and provides a descriptive summary of the data logged. However, relating this summary information to the raw data file of individual readings, which can be generated from the original machine language file, is a cumbersome process if additional analyses are necessary.

Advantages/Disadvantages

The following Ranger features were considered advantages:

1. Software is provided with the data logger to upload logged data, to perform limited statistical analyses, to provide printed graphic output, and to create relatively clean ASCII data files of individual raw data readings for time periods of 1 second or greater.
2. The capability to handle many different types (e.g., DC current, temperature and RPM) and ranges of input is available.
3. The Ranger is a relatively inexpensive data logger.

These features were considered disadvantages:

1. The Rustrak is not shielded against EMI.
2. The minimum sampling period is 0.65 second.
3. If the data can be represented by internally stored algorithms, individual data points are not logged each 0.65 second but are approximated.
4. An interface pod must be used to convert the input signal to a standard scaled signal level.

Conclusions and Recommendations

Characterization of worker exposure to RF radiation can be greatly improved by using an appropriately adapted data logger with an RF survey meter. The additional data derived from the data logging can be handled readily with microcomputers and reduced to a meaningful exposure characterization graphically and statistically.

Each commercially available data logger has advantages and disadvantages for measurement of industrial RF radiation sources. Most of the operational problems encountered with the Holaday and Ranger data loggers could be resolved to varying degrees of satisfaction for RF measurements applications. Adequate EMI shielding, short sampling frequencies, real data representation, direct data accessibility, and cost factors must be weighed against the intended use of the data logger.

References

1. Lerner, E.L.: RF Radiation: Biological Effects. IEEE Spectrum 17:51 (1980).
2. Murray, W.E.; Lary, J.M.; Conover, D.L.: A Process to Develop a Recommended Standard for Occupational Exposure to Radiofrequency and Microwave Radiation. In: 17th Annual National Conference on Radiation Control. Conf. Publication 85-3. Conference of Radiation Control Program Directors, Inc., Frankfort, KY (December 1985).
3. U.S. Department of Labor, OSHA: Nonionizing Radiation. Safety and Health Standards, 29 CFR 1910.97 (1981).
4. American Conference of Governmental Hygienists: Threshold Limit Values and Biological Exposure Indices for 1987–1988. ACGIH, Cincinnati, OH (1987).
5. American National Standards Institute: Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 300 kHz to 100 GHz. Report No. ANSI C95.1–1982. ANSI, New York (1982).
6. Tell, R.A.: Real-Time Data Averaging for Determining Human RF Exposure. In: Proceedings 40th Annual Broadcast Engineering Conference. National Association of Broadcasters, Dallas, TX (April 1986).
7. Edwards, R.M.; Cox, C.; Grajewski, B.A.: A Computer Program for Use with the Holaday HI-3320 or Metrosonics dl-332 Data Logger. Appl. Ind. Hyg. 4(11):291 (1989).

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