HI-3510

RF Radiation Badge
Broadband Electromagnetic
Radiation Detector

User's Manual

Declaration of Conformity

We,
HOLADAY INDUSTRIES, INC.
14825 MARTIN DRIVE
EDEN PRAIRIE, MN 55344
USA

CE

declare in our own responsibility, that the HOLADAY product described in this instruction manual is in compliance with: EN EMC Directive 89/336/EEC, EN50082-1, EN55011

President
HOLADAY INDUSTRIES, INC.

Manual #600071 10/97 $20.00

Revision Record

Manual #600071
HI-3510 Radiation Badge
Broadband Electromagnetic Radiation Detector

Revision	Description	Date
---	Release	11-6-96
A	Added CE Label	10-10-97

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Limited Warranty

Holaday Industries, Inc. warrants each model HI-3510 Radiation Badge Broadband Electromagnetic Radiation Detector to be free from defects in material and workmanship for a period of one year from the date of shipment to the purchaser. This warranty extends to the original purchaser only, and does not apply to the batteries or to any products or parts subject to misuse, neglect, accident, unauthorized service or abnormal conditions of operation.

In the event an instrument covered by this warranty fails, Holaday Industries, Inc. will, without charge, repair and recalibrate the instrument if returned to their factory within one year of the original purchase—provided that Holaday Industries' examination discloses, to its satisfaction, that the product is defective. Holaday Industries, Inc., may, at its option, replace the product in lieu of repair. If the defect was caused by misuse, neglect, accident, unauthorized service or abnormal conditions of operation, repairs will be billed at a nominal cost. In such cases, an estimate will be provided before work is started, if requested by the purchaser.

For warranty service, contact Holaday Industries, Inc. Provide the serial number of the instrument and complete details regarding the failure mode. You will then be given either service information or shipping instructions. Return the instrument to the factory, transportation prepaid. Repairs will be made at the factory and the instrument will be returned to you, transportation prepaid. Holaday Industries, Inc., assumes no responsibility for loss of, or damage to, products in transit.

Warning!

EXTREME CAUTION IS ADVISED WHEN WORKING IN ENVIRONMENTS WHERE HIGH-INTENSITY ELECTROMAGNETIC FIELDS MAY EXIST AND WHERE CONTACT WITH HIGH VOLTAGE OR HIGH CURRENT CIRCUITS OR APPARATUS IS POSSIBLE. ACCIDENTAL CONTACT WITH OBJECTS OR CIRCUITS OPERATING AT HIGH VOLTAGES OR HIGH CURRENTS CAN BE LETHAL! HOLADAY INDUSTRIES, INC. ASSUMES NO LIABILITY FOR ANY

WARNING:

Harmful effects may result from exposure to electromagnetic (EM) radiation in the frequency range from 300 kHz to 100 Ghz.

Among the more widely accepted safety standards are those established by the American National Standards Institute ("ANSI"), C95.1-1991, and the National Radiological Protection Board (“NRPB”), NRPB-G11, of the United Kingdom. Each of the two standards establishes different safety limits for the general public and industrial environments. Of particular significance is the 10 to 300 MHz frequency range, where the limits are most stringent, especially for the general public, and are set to an equivalent power density of 0.2 mW/cm^2. At higher frequencies, the limits are as high as 1 mW/cm^2, whereas at frequencies below 3 MHz, the limits are set to 100 mW/cm^2.

Note that the aforementioned safety standards cannot be measured by the Model H600A, which is a warning, and not a measuring device. Suitable measuring devices exist in the marketplace. Please contact the factory for additional information on this subject.

The three common units of measurement for characterizing electromagnetic energy are power density in mW/cm2, electric field ("E-field") in V/m and magnetic field ("Hfield") in A/m. At sufficiently large distances from the source of radiation, the E-field and H-field components have a fixed mathematical relationship. Thus, the measurement of any one of these units in free space is sufficient to determine the radiation level and derive the other two. At frequencies nominally above 1

GHz, most radiation fields are of this character known as the free space condition. The free space relationships are shown below:

To convert:

Power Density P in mW/cm^2 to Electric Field E in V/m: $E = 61.4\ (P^{0.5})$

Power Density P in mW/cm^2 to Magnetic Field H in A/m: $H = 0.163\ (P^{0.5})$

Always approach an unknown field cautiously, starting from as far away as possible and extending the RF Radiation Badge at arm's length toward the energy source. Allow two to three seconds for the instrument to respond. Observe all safety precautions. Do not walk into a suspected radiation field until the power density is determined to be safe. Ensure that the unit is in the "Instantaneous" Measurement Mode (see paragraph 3-4-3-2), not the "Average" Measurement Mode.

SECTION I
INTRODUCTION

1-1 General

The Model HI-3510 Broadband Electromagnetic Radiation Detector (see figure 1) is a portable, battery operated, non-ionizing radiation hazard detector intended for personal use. It detects electromagnetic radiation from RF and microwave sources in the frequency range from 0.05 to 2.5 GHz and alerts the user to potentially hazardous fields. The Model HI-3510 enables the user to set the alarm warning level anywhere in the range from 0.2 to 20 mW/cm^2. In addition, the user can choose either of two measurement modes: instantaneous exposure level or a six minute average measurement. Both modes are displayed on a three digit LCD panel along with a ten segment bar graph normalized to the selected alarm warning level. Electrical, mechanical and performance characteristics are described in table 1 below.

The Model HI-3510 is intended for use by personnel who work with or service RF and microwave equipment such as:

- Microwave Ovens
- Medical Equipment
- Microwave Heaters and Dryers
- Communication Systems
- Cellular Telephones

SECTION II
SPECIFICATIONS

FEATURE	DESCRIPTIVE DATA
FREQUENCY RANGE:	50 MHZ TO 2.5 GHz
POWER DENSITY RANGE:	0.01 TO 20 mW/cm^2
ALARM ACCURACY:	±2 dB
RESPONSE:	Isotropic
RF DETECTION:	Diode
AVERAGE POWER OVERLOAD:	1 W/cm^2
PEAK POWER OVERLOAD:	100 W/cm^2
POWER DENSITY INDICATORS:	A) 3 Digit LCD B) Bar Graph
MEASUREMENT MODES:	A) Instantaneous Power Density B) 6 Minute Average Power Density
BAR GRAPH DISPLAY:	Percent of Set Alarm Level
ALARM LEVEL SETTINGS:	0.2 to 20 mW/cm^2
ALARM SIGNALS:	A) Flashing LCD Indicator B) Flashing LED C) Audible Beep
BUILT IN TEST:	Continuous
BUILT IN TEST FUNCTIONS:	A) Detector Fault B) Low Battery
TEMPERATURE RANGE: Operating Storage	 10/C to + 55/C 40/C to + 65/C

Table 1
Model HI-3510 Technical Specifications

SECTION III
OPERATION

3-1 General Information

The Model HI-3510 can be carried inside outer garments, fastened to a shirt or jacket pocket, or to a belt using the clip provided on the instrument. Metallic objects such as a belt buckle, pen, pencil, etc., could affect the accuracy of the Model HI-3510. Do not locate the unit near any metallic object.

NOTE:
The side of the unit containing the clip should always face toward the wearer's body.

3-2 Safety Precautions

The following precautions should be observed when entering an area where unsafe radiation levels may be expected.

1. Turn on the Model HI-3510. Set it to the "Instantaneous" Measurement Mode as described in paragraph 3-4-3-2.
2. Enter the area and do a "walk-around". Should the Model HI-3510 indicate that an alarm condition exists, take corrective action by turning off the source of RF power or leaving the area immediately.
3. Keep the Model HI-3510 turned on and continue to wear it as long as you are in the area.

3-3 Operating Controls and Indicators

The operating controls on the Model HI-3510 are the ON-OFF switch and the MODE switch, both of which are located on the side of the unit. In addition, the Model HI-3510 has three alarm indicators: Two visual indicators consisting of an LCD display panel and red LED warning light, both located on the top of the unit (see figure 2), and an audible alarm produced by a beeper located with the unit. In addition, there is an audio output jack to which the furnished acoustical earpiece can be connected.

3-4 Operating Procedure

To turn the unit ON, place the ON-OFF switch in the ON position. The unit will respond with a three second beep and its red LED will glow to confirm that the unit is operational. In addition, all segments of the LCD display will be on during this three second interval. The LCD display will then indicate the preset alarm warning level for about seven seconds. The unit will then respond with a short beep and red LED flash. At this time; the unit is operational and will indicate the power density in the area as well as the ratio of the power density in the area to the preset alarm warning level (% ALARM LEVEL bar graph). This display is normalized to the programmed alarm level so that the alarm indicates when the bar graph reaches 100%. Using this display, the wearer can tell how close he or she is to the alarm without being exposed to an alarm power level. (If you are working in a noisy environment, connect the acoustical earpiece to ensure hearing the audible alarm.) When there are no RF fields present higher than the preset alarm warning level, there will be no further alarm indications from the unit.

Should the unit detect a field that exceeds the preset alarm warning level, the unit will start to beep and flash. The beep and the flash rate are directly proportional to the RF field strength above the alarm set value (see 3-4-2). Note that once the alarm starts, it will latch at the minimum flash rate, continuing to warn of an over-exposure even if the RF field that caused the alarm is no longer present. In order to reset the alarm function, the unit must be turned OFF and back ON using the ON-OFF switch. For information concerning disabling the latch function, refer to paragraph 3-4-4. For information concerning "Instantaneous" vs "Average" measurement modes, refer to paragraph 3-4-3.

HI-3510 Display Features

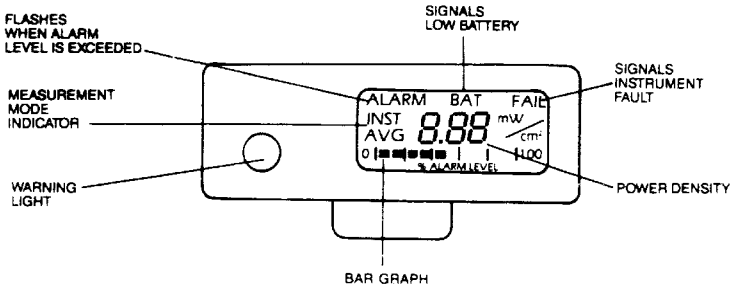

FIGURE 1
MODEL HI-3510 DISPLAY

3-4-1 Set-Up Mode

The "Set-up" mode is used to set the alarm warning level and to enable/disable the audible alarm. To enter this mode, set the "ON-OFF" switch to ON. Then depress the MODE switch after the initial three second period referenced in paragraph 3-4. The LCD display will indicate "S.U.". At this point, the alarm warning level can be changed (paragraph 3-4-2).

3-4-2 Setting Alarm Warning Level

In the "Set-Up" mode (paragraph 3-4-1), depress and hold the MODE switch. After three seconds, the preset alarm warning level will be displayed. Release the MODE switch. Depressing and holding the MODE switch again at this point will result in a rapidly increasing alarm warning level indication. Continue to depress the MODE switch until the desired alarm level is approached. Then, release the MODE switch and pulse it at a convenient rate until the desired alarm warning level is reached. Once it is reached, set the ON-OFF switch to OFF and then to ON again. The alarm warning level that has just been set will remain in memory until changed again as described above.

3-4-3 Measurement Modes

The Model HI-3510 Measurement Mode can be set to either "Instantaneous" or "Average" by depressing and releasing the MODE switch while the unit is in its normal operating mode. See paragraphs 3-4-3-1 and 3-4-3-2.

3-4-3-1 “Average” Measurement Mode

When the AVG annunciator on the left side of the display area is visible, a six-minute running average is maintained by the unit. Power density is sampled every 3.6 seconds. During the first six minutes (i.e.-360 seconds or 100 measurements), the running average of all measurements taken will be displayed. After six minutes, each "new" measurement will replace the measurement taken 363.6 seconds prior to that "new" measurement. Therefore, the average of the most recent 100 measurements will always be displayed.

The average of the latest 100 measurements is also compared by the unit to the alarm warning level set by the operator (paragraph 3-4-2) to determine the % ALARM LEVEL ratio. (During the first six minutes of operation, the running average of all measurements taken will be compared by the unit to the alarm warning level set by the operator to determine the % ALARM LEVEL ratio.) If the % ALARM LEVEL ratio reaches 100%, the unit's alarm circuitry will be activated, the red LED and the ALARM annunciator on the LCD will flash every 3.6 seconds, and the audible alarm will sound every 3.6 seconds.

3-4-3-2 "Instantaneous" Measurement Mode

When the INST annunciator on the left side of the LCD display area is visible, the measured power density is sampled and displayed every 1.8 seconds. (Note that the Model HI-3510 saves data for six minutes regardless of the display selected. Switching between "Average" and "Instantaneous" does not affect the data being stored.)

3-4-4 Latched Alarm

A feature of the unit's alarm system is that the beeps and flashes are progressive. Once the alarm level has been reached, the unit will indicate a single beep and flash each 1.8 seconds with the "INST" annunciator displayed or 3.6 seconds with the "AVG" annunciator displayed. Should the unit detect a field that exceeds the preset alarm level, the unit will start to beep and flash. The beep and the flash rate are directly proportional to the RF field strength. Note that once the alarms start, they latch at the minimum flash rate, continuing to warn of an over exposure situation even if the RF field that initially caused the alarm is no longer present. In order to reset the alarm function, it is necessary to turn the unit OFF and back ON using the ON-OFF switch. If it is desired to disable the latch function, follow the turn-on procedure described in paragraph 3-4 except depress and hold the MODE switch before placing the ON-OFF switch to the ON position.

3-4-5 Built-In Test Functions

The unit generates a beep and flash at turn on to verify that the alarm indicators are functioning. At this time, all segments of the LCD display are enabled to indicate that the display is operating properly. Ten seconds after turn on, the unit will generate a second beep and flash which indicates that it is operational. A low battery condition is indicated if the unit beeps and flashes two times after the ten second period. To verify, check the LCD display for a "BAT" indication. In addition, the battery condition is tested automatically every minute. Should the battery measure low, the "BAT" indicator will flash and the unit will beep and flash once a minute. Refer to Section V for battery replacement procedures.

The unit also contains continuous fault detection circuitry to alert the user to an RF detector failure. In that event, the beeper and light will start to beep and flash at a constant rate, and the LCD display will indicate "FAIL". The unit is no longer usable in this condition and should be turned off and serviced.

SECTION IV
THEORY OF OPERATION

4.1 GENERAL

The Model HI-3510 is a portable, battery operated, non-ionizing radiation hazard detector intended for personal use. It detects electromagnetic radiation from RF and microwave sources in the frequency range from 0.05 to 2.5 GHz and alerts the user to potentially hazardous fields. The Model HI-3510 enables the user to set the alarm warning level anywhere in the range from 0.2 to 20 mW/cm^2. In addition, the user can choose either of two measurement modes: instantaneous exposure level or a six minute average measurement. Both modes are displayed on a three digit LCD panel along with a ten segment bar graph normalized to the selected alarm warning level.

4.2 MAGNETIC FIELD SENSOR

The Model HI-3510 uses an isotropic array of tandem loops, each feeding a Schottky diode detector. The outputs of these loops are summed to a common feed line. Utilizing a unique cancellation scheme, the resulting rectified voltage represents only the magnetic field component. The electric field component is canceled out and does not appear in the measurement. The diodes are operated in their low level region to assure square law performance.

4-3 DC CIRCUIT

The DC output produced by the RF circuit is amplified by a differential chopper-stabilized amplifier. This circuit has

high common mode rejection and low DC drift. The high level output of this circuit is connected to a micro controller which has a built in A/D converter. The amplifier has two gain ranges that are controlled by the micro controller.

A self-contained test signal is constantly applied to the RF detector. Should a fault occur in this circuit, a fault signal is generated through the DC amplifier which then generates a fault bit to the micro controller.

The analog output from the DC amplifier is digitized by the micro controller's A/D converter. The reference voltage for the A/D converter is generated from a band-gap reference diode which provides excellent long term stability. The micro controller then controls the measurement rate for instantaneous or average measurements, amplifier ranges, LCD display, fault indications and low battery signals. It stores and computes the data for the six minute average readout and stores the alarm warning level trip point.

4-4 RF SHIELDING

To enable accurate operation of the sensitive circuits within the RF Radiation Badge in the presence of RF fields, an array of shields and absorbers is used. The circuits are contained within a Faraday shielded area which is then covered by a graded absorber to minimize field disturbances.

SECTION V
MAINTENANCE

5-1 GENERAL

The Model HI-3510 been designed for rugged field use. Normal maintenance for this unit consists only of battery replacement and calibration.

5-2 BATTERY REPLACEMENT

The unit comes furnished with a D12450B lithium cell. Normal operating life is 1000 hours. With the alarm in its latched mode, the battery life is about 80 hours. The shelf life of the battery is about ten years when stored in a cool environment.

The unit has a built in battery monitoring circuit that generates a single beep and flash at one minute intervals under low battery conditions. To replace the battery, proceed as follows:

1. Turn the unit off. **THIS IS IMPORTANT**.

2. Slide open and remove the battery cover.

3. Note the position of the battery and the battery removal strap. To remove the battery, pull the strap straight out until the battery can be removed.

4. Insert the new battery, making sure the new battery and the battery removal strap are in the positions noted in step 3 above.

5. Turn the unit on. The instrument should now be operational and the one minute beep and flash

warning indicators should cease.

5-3 TROUBLE SHOOTING

NOTE:
In general, except for normal battery replacement, trouble shooting and repair of this instrument by the user is not recommended.

5-3-1

As part of its self-test capability, the unit will produce a tone and flash when it is turned on. In the event it fails to do so, check the condition of the battery by replacing it in accordance with the procedure described in paragraph 5-2 above.

Should the unit continue to malfunction, return it to Holaday Industries for repair.

SECTION VI
CALIBRATION

6-1 GENERAL

The Model HI-3510 should be calibrated at 12 month intervals. To do so requires the use of highly specialized test equipment and facilities, such as a radio-frequency anechoic chamber and TEM cells, wherein fields of known power density can be accurately established. It should also be noted that to establish the required power densities will require CW sources of 10W or greater together with accurately calibrated test antennas and power monitoring equipment. If facilities of this type are not available, the unit should be returned to Holaday Industries or to another qualified calibration facility for this service.

6-2 CALIBRATION PROCEDURE

6-2-1 Set the alarm warning level to 0.5 mW/cm^2 as described in paragraph 3-4-2.

6-2-2 Disable the latch function as described in paragraph 3-4-4.

6-2-3 Following the procedures described below, position the unit in a 50 - 500 MHZ TEM cell and in a 900 MHZ to 2.5 Ghz anechoic chamber. The preferred orientation of the E-field is parallel to the vertical axis of the unit.

6-2-4 At each test frequency, raise the power density level at the unit until an alarm is indicated. Record this power density level on the test data sheet in mW/cm^2.

6-2-5 Perform the test described in paragraph 6-2-4 as follows:

In the TEM cell, test at 50, 300 and 500 MHZ
In the anechoic chamber, test at 0.9, 1.2 and 2.5 GHz

6-2-6 From the data in paragraph 6-2-5, calculate the average power density measured over the band by taking the square root of the product of the highest and lowest readings recorded. Record the resultant on the data sheet for P_{CAL}.

6-2-7 Divide 0.5 mW/cm^2 by the power density level recorded on the data sheet for P_{CAL}. This determines the correction multiplier, M.

6-2-8 Alignment can now be performed at any one of the calibration frequencies specified in step 6-2-5. Select a convenient calibration frequency.

6-2-9 At the selected calibration frequency, multiply by M the indicated power density from the data recorded in paragraphs 6-2-4 and 6-2-5 above. Record this as P_{REF}.

6-2-10 Locate the calibration potentiometer access hole behind the "Made in USA" label. Remove the label only if adjustment is needed.

6-2-11 Apply the P_{REF} power at the calibration frequency. Adjust this potentiometer such that the alarm just starts to indicate. Repeat this adjustment as required.

6-2-12 This completes the RF calibration. Replace the "Made in USA" label. Attach a new calibration

sticker with the current calibration date.

NOTE:
Do not place any stickers or labels that contain metal on the bottom surface of the unit or the lower portions (i.e., approximately 1 ½ inches up from the bottom surface) of the front and both sides of the unit. This could seriously affect the accuracy of the unit. Paper or plastic stickers are acceptable.

6-3 TEST DATA SHEET MODEL HI-3510

DATE	SERIAL NUMBER	TESTED BY
PARA 6-2-4 AND 6-2-5		
FREQUENCY (GHz)	POWER DENSITY LEVEL (mW/cm^2)	
0.05		
0.3		
0.5		
0.9		
1.2		
2.5		
PARA 6-2-6	$P_{CAL} = (P_{HI}\ P_{LO})^{0.5} =$	
PARA 6-2-7	$M = \frac{0.5}{P_{CAL}} =$	
PARA 6-2-8	CAL FREQ =	
PARA 6-2-9	P_{REF} = M (POWER DENSITY = AT CAL FREQ)	
PARA 6-2-11	ALARM SET FOR P_{REF} _____ CHECK	

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