

**DEPARTMENT OF THE NAVY**

NAVAL SURFACE WARFARE CENTER
DAHLGREN DIVISION
17320 DAHLGREN ROAD
DAHLGREN, VIRGINIA 22448-5100

IN REPLY REFER TO

10550
J52-6380ZAN

SEP 29 1998

From: Commander, Dahlgren Division, Naval Surface Warfare Center
To: Integration Logistic Agency
Attn: LOIA-LF (John Waddick)
5001 Eisenhower Ave.
Alexandria, VA 22333-5001

Subj: HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO)
SAFETY EVALUATION TESTS OF ARMY AMMO AUTOMATIC
IDENTIFICATION TECHNOLOGY (AIT) EQUIPMENTS

Ref: (a) MIL-STD-461D Requirements for the Control of
Electromagnetic Interference Emissions and
Susceptibility
(b) MIL-STD-462D Measurement of Electromagnetic
Interference Characteristics

Encl: (1) Hazards of Electromagnetic Radiation to Ordnance
(HERO) Safety Evaluation Test Results for Automatic
Identification Technology (AIT) Equipments

1. As requested by the Army Integration Logistics Agency (LOIA)/Mr. John Waddick, Code LOIA-LF, HERO safety evaluation tests were conducted on four items of the Army Ammo AIT equipments (here-in-after referred to as AIT equipment). These evaluations were conducted during the period of 23 March through 03 April, and 26 through 29 May 1998. The evaluations were based on the results of an analysis of the output signal spectrum characterization, and/or results of Radiated Emission (RE102) tests to the requirements of reference (a), for each item. Where appropriate, the tests were accomplished in accordance with procedures specified in reference (b). The equipments subjected to test and evaluation were as follows:

a. Savi MobileReader 410R - Portable Hand held RF interrogator w/bar code and RFID capabilities only.

b. SaviReader 410R - Fixed location RF Interrogator. Model #410R-001.

c. Savi GateReader 410R - RF Gate Sensor/Interrogator/Checkpoint Tracking System.

d. Redesigned SaviTag 410.

2. The potential effect of the output signal levels of the Savi

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transceivers on Electro-Explosive Devices (EED)s was also investigated during these efforts.

3. The results of the output signal spectrum analysis, RE102 tests, and transceiver output signal level effect on EEDs, as well as the conclusions and recommendations which are based on those results are presented in enclosure (1).

4. Please direct any questions, or comments, to Benton C. Zander Code J52, commercial (540) 653-3435 or DSN 249-3435.



L. J. FONTENOT
By direction

Copy to:
Commander, Naval Ordnance Center
(Code N7132/C. Wakefield)
Farragut Hall, Bldg D323
23 Strauss Avenue
Indian Head, MD 20640-5555

Commander, Crane Division, Naval Surface Warfare Center
(Code 4035/J.E. Werne)
300 Highway 341
Crane, Indiana 47522-5001

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**HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE
(HERO) SAFETY EVALUATION TEST RESULTS
FOR THE
ARMY AMMO AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT)
EQUIPMENT**

May 1998

Distribution authorized to DOD personnel and DOD Contractors only;
Test and Evaluation; April 1998. Other request for this document
must be referred to Commander, Dahlgren Division, Naval Surface
Warfare Center, Code J52, 17320 Dahlgren Road, Dahlgren, Virginia
22448-5100

Encl (1)

**HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO) SAFETY
EVALUATION TEST RESULTS FOR THE ARMY AMMO
AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT) EQUIPMENT**

Ref: (a) MIL-STD-461D
(b) MIL-STD-462D
(c) Hazards of Electromagnetic Radiation to Ordnance
(HERO) Safety Evaluation Test Plan for the Army's
Automatic Identification Technology (AIT) Ammo Tracking
Equipment

I. GENERAL

1. During the period of 23 March through 03 April, and 26 through 29 May 1998, tests and analysis were performed to determine the output signal spectrum characteristics, and/or the Radiated Emissions (RE102) of four (4) items of the US Army's Ammo AIT equipments. The tests to determine the output signal spectrum characteristics of the AIT equipments were conducted as a means of evaluating the safety of using these AIT equipments in close proximity to ordnance. The RE102 tests and evaluations were conducted to determine the potential for the AIT equipments to effect the operation of other sensitive electronic equipments. The RE102 tests were conducted, to the extent possible, as specified in the requirements and procedures delineated in references (a) and (b). The tests were conducted in accordance with reference (c), which is included as attachment (1) for information purposes.

2. The AIT equipments evaluated were as follows:

- a. Savi MobileReader 410R - Portable Hand held RF interrogator w/bar code and RFID capabilities only. [Model #SMR-410-200, Serial No. 98020400443 (Unit #1), Serial No. 98020400432 (Unit #2), and Serial No. 98032400481 (Unit #3)]
- b. SaviReader 410R - Fixed location RF Interrogator. Model #410R-001, Serial No. 2014, and Model # SR410R-006 S/N 3803
- c. Savi GateReader 410R (RF Gate Sensor/Interrogator/Checkpoint Tracking System). (See Paragraphs II.1 and IV.1.c for Model/Serial Numbers of system components subjected to Tests and evaluation.)
- d. SaviTag 410 - RF Identification Device. Model #ST-410-118, Serial No. 0011412

3. Most of the AIT equipments subjected to tests and evaluation, are intentional transmitters, which are intended for use in close proximity to ordnance items. Therefore, we considered it essential that the safe separation distance for each AIT item be determined. In the case of hand held interrogators, it was determined that they

would normally be operated at a distance of 4 to 12 inches from ordnance items to scan a bar code label and "write" the data to a SaviTag using the on-board transmitter of the hand held interrogator. The SaviTag is a transceiver, which is intended to be mounted on ordnance shipping containers and/or pallets, and it's output signal level was, therefore, also measured at a distance of four (4) inches.

4. The Electro-Explosive Devices (EED)s used in Army, and Navy ordnance vary considerably (depending upon the application) in the Maximum No Fire Stimulus (MNFS) that they can withstand without firing. MIL-STD-464, DEPARTMENT OF DEFENSE INTERFACE STANDARD, Electromagnetic Environmental Effects Requirements for Systems, states that "Ordnance shall have a margin of at least 16.5 dB of maximum no-fire stimulus (MNFS) for safety assurances and 6 dB of MNFS for other applications." This requirement categorizes RF currents induced in an EED which exceed 15% of the MNFS as a potential safety concern, and 50% of the MNFS as being a potential reliability concern. Therefore, during this effort we considered it essential to quantify the level of RF energy necessary to induce 15% of the MNFS in a given perfectly matched EED circuit.

II. TEST CONFIGURATION

1. RE102 Test Configuration: The test configuration required by reference (b) was modified to more closely reflect the manner in which the AIT equipment would be configured and used in the field. For example the ground plane (copper top bench) was not used for this testing.

The Savi GateReader 410R Prototype Controller (Part No. 860-01620-001, Serial No. 2810), and the fiber optic Router (Raytheon Control-By-Light, Model #75090-2/SMA, Serial # VC97-0101) with associated cables were the only AIT items subjected to RE102 tests and evaluations during these efforts. During discussions with the Savi on-site personnel, we were informed that the Fiber Optic Router will usually be located in the Controller module, but may be installed by itself within 3 to 5 inches of the Controller Module. The integration of the Controller and Router into a single module could result in considerable variation in cable and interconnecting lead length, as well as possible interaction between the two units. For these tests and evaluations, the Savi GateReader controller, and the Fiber Optic Router were both mounted on the same metal panel, and all fiber optic and cabling to the rest of the system were run through a small port in the wall of the screen room. It should be noted that the Savi on-site representative informed us that the 433.92 MHz antenna and transceiver have been removed from the Controller enclosure and installed in a separate enclosure. The Controller was a "breadboard" configuration rather than a production unit. The test configuration is shown in figure 1.

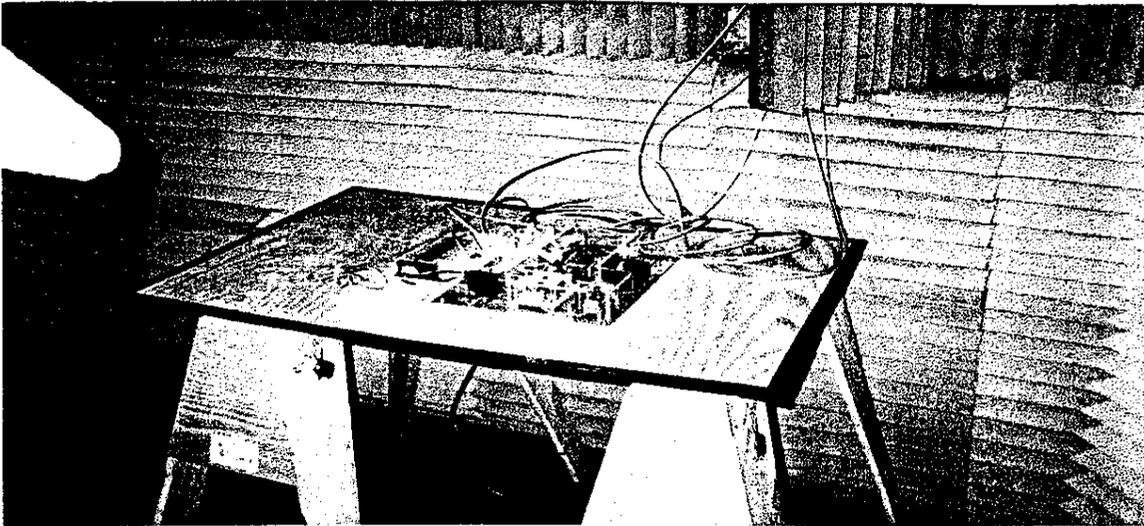


Figure 1. Savi GateReader components configured for RE102 tests.

2. Output Signal Spectrum Analysis Configuration: This analysis of the output signal spectrum was conducted on the Savi MobileReaders (410R), GateReader (Savi 410GR) Transceiver/Antenna modules, SaviReader (410R), and SaviTag (410) output signals. A special antenna test fixture was constructed to facilitate the analysis of the output signal spectrum characteristics of these units. The antenna test fixture, here-in-after referred to as "the fixture," was designed and constructed to establish a fixed measurement distance, between the radiating and receptor antennas, of either four (4) inches or twelve (12) inches. The fixture consists of a .125"x 14"x 21" aluminum plate, with three (3) antenna ports set at four (4) and twelve (12) inches apart. The aluminum plate is mounted on 1 3/4" wood spacers to allow space, beneath the plate, for the connection of low-loss cables from the interrogator antenna port, and to the spectrum analyzer.

However, since we were not able to obtain the connectors to mate the low loss cable with the hand held interrogator's antenna port, it was necessary to place the interrogators in a cradle on top of the fixture plate, and establish the distance between the interrogator antenna and the fixture antenna.

For the analysis, the Savi MobileReaders 410R, Mod. #SMR-410-200 were programmed to repeatedly scan a bar code label, transmit the data to a SaviTag, query the Tag to ensure that the data was "written" in its memory, and store the data to be down-loaded at a later time. The SaviTag was placed on the fixture at a distance of twelve (12) and then four (4) inches to determine the minimum safe separation distance from ordnance. The fixture is shown in figure 2, and the test configuration with the interrogator in the cradle is shown in figure 3.

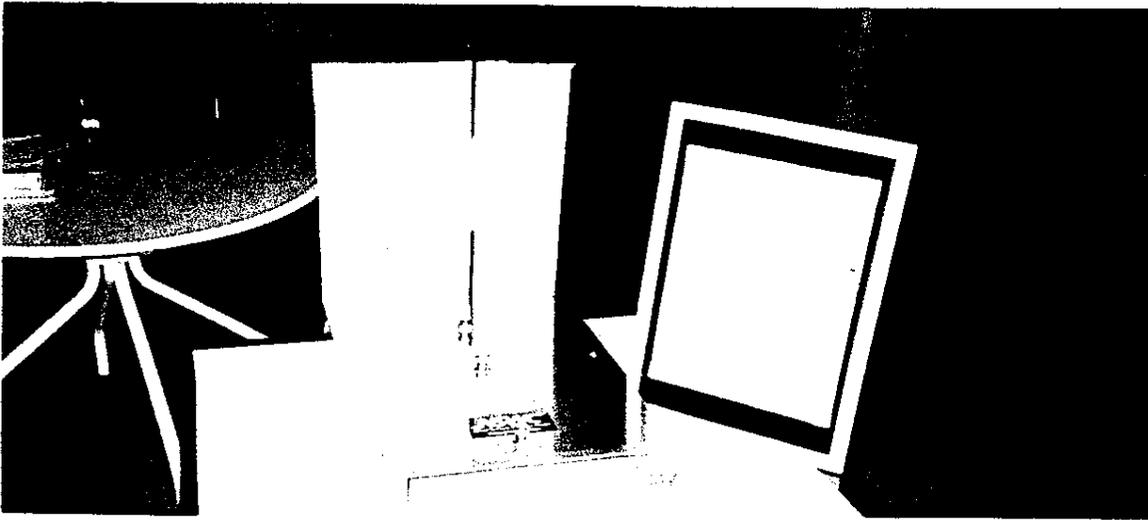


Figure 2. Antenna test fixture.

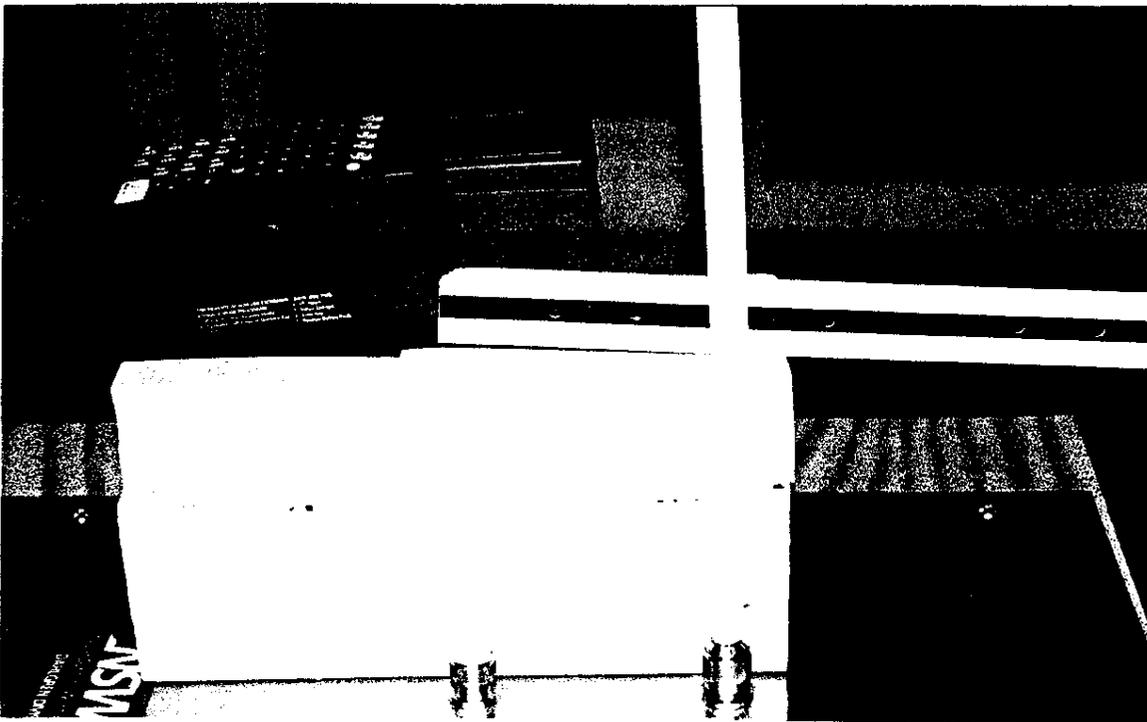


Figure 3. Savi MobileReader configured for analysis

Although the fixture was constructed to be used for analysis of the output signal of the hand held interrogators, it proved quite useful, when fitted with the proper antenna(s), in the analysis of the output signals of the SaviReader, GateReader, and

SaviTag. The output signal analysis configurations for these equipments are shown in figure 4, figure 5, and figure 6.

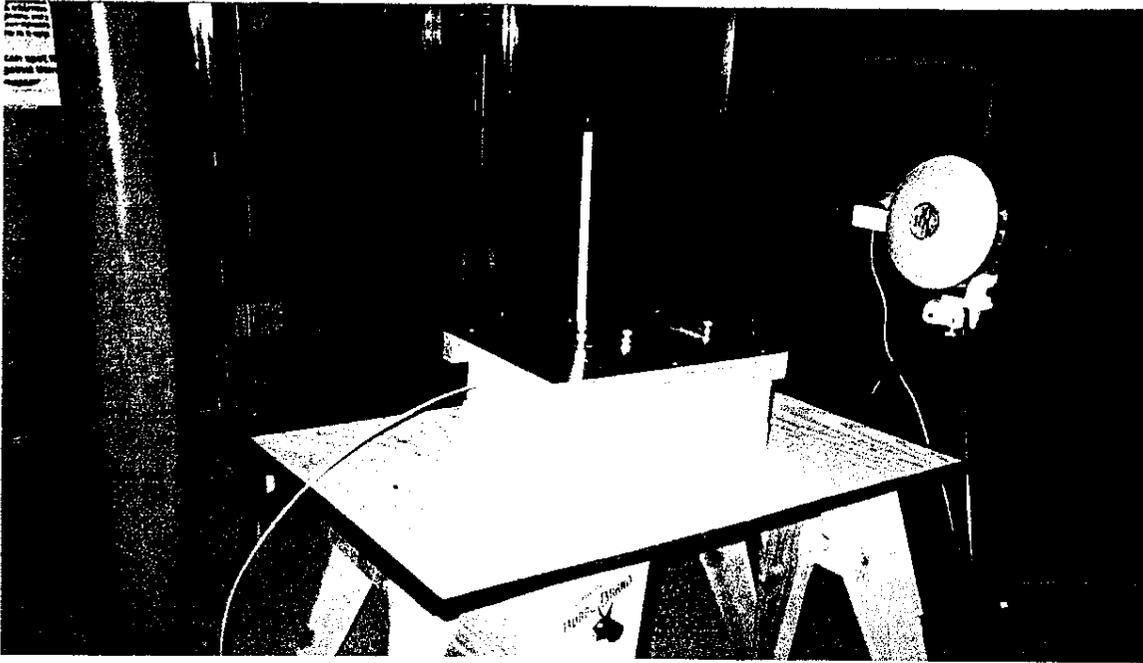


Figure 4. SaviReader 410R configured for analysis.

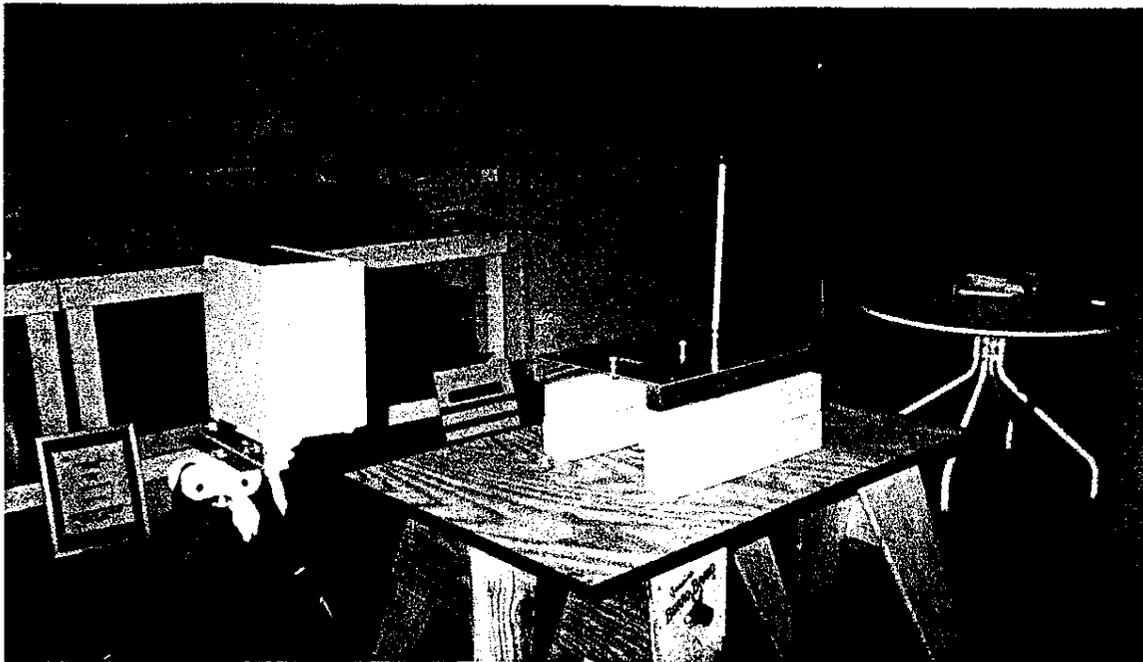


Figure 5. Savi GateReader 410R Transceiver configured for analysis.

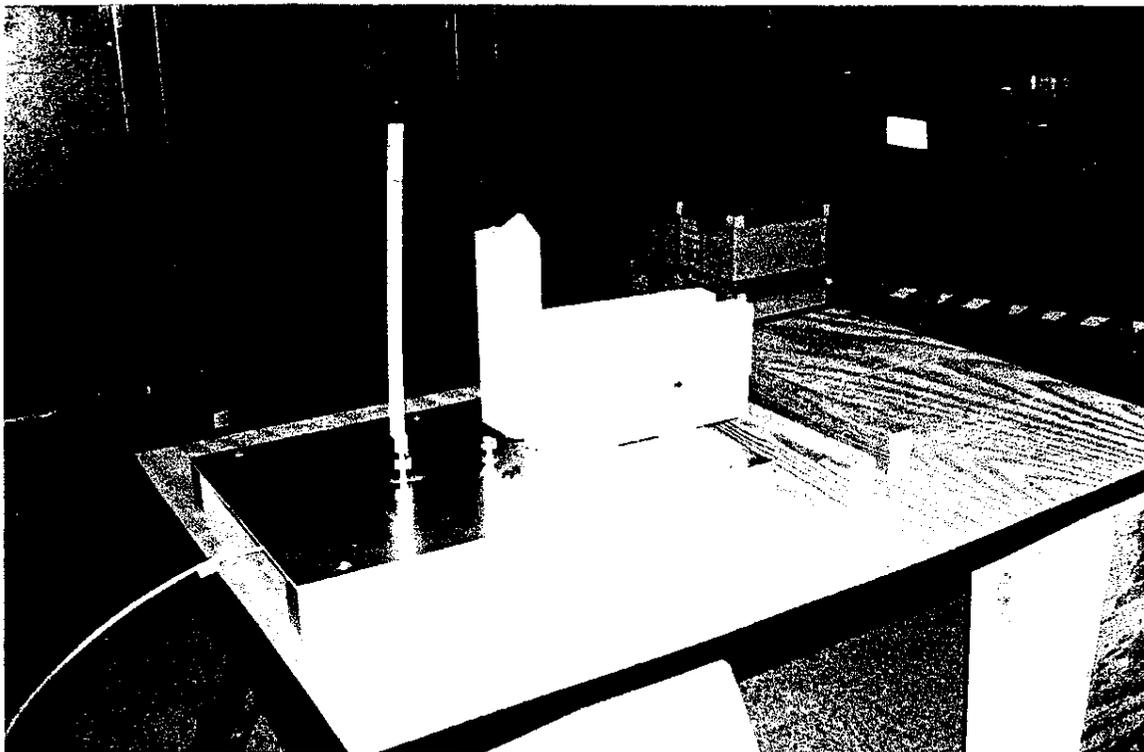


Figure 6. SaviTag 410 Transceiver configured for analysis.

3. **EED Investigation Configuration:** For this investigation, four different types of antennas (dipole, loop, shorted pair, and rod) were fabricated as full wavelength at 433.92 MHz, and each was fitted with an instrumented EED. The four antenna and EED configurations were initially as presented in Table 1.

Table 1. Initial antenna/EED configuration

Antenna	EED	BW Resist	MNFS
a. Dipole	Mk71 (S/N 16957)	5.0 Ohms	94 mA
b. Loop	S75 (S/N 14657)	2.4 Ohms	100 mA
c. Shorted pair	T20E1 (S/N 15493)	3.2 Ohms	100 mA
d. Rod	Mk71 (S/N 16948)	5.0 Ohms	94 mA

The antennas and EED configurations were then each placed on the Antenna Fixture at a distance of four (4) inches from the source antenna. The EED Bridge Wire (BW) current was monitored via fiber optic cables to fiber optic receivers connected to four channels of a Metricor eight channel recorder/plotter. The Antenna/EED test configuration is shown in figure 7.

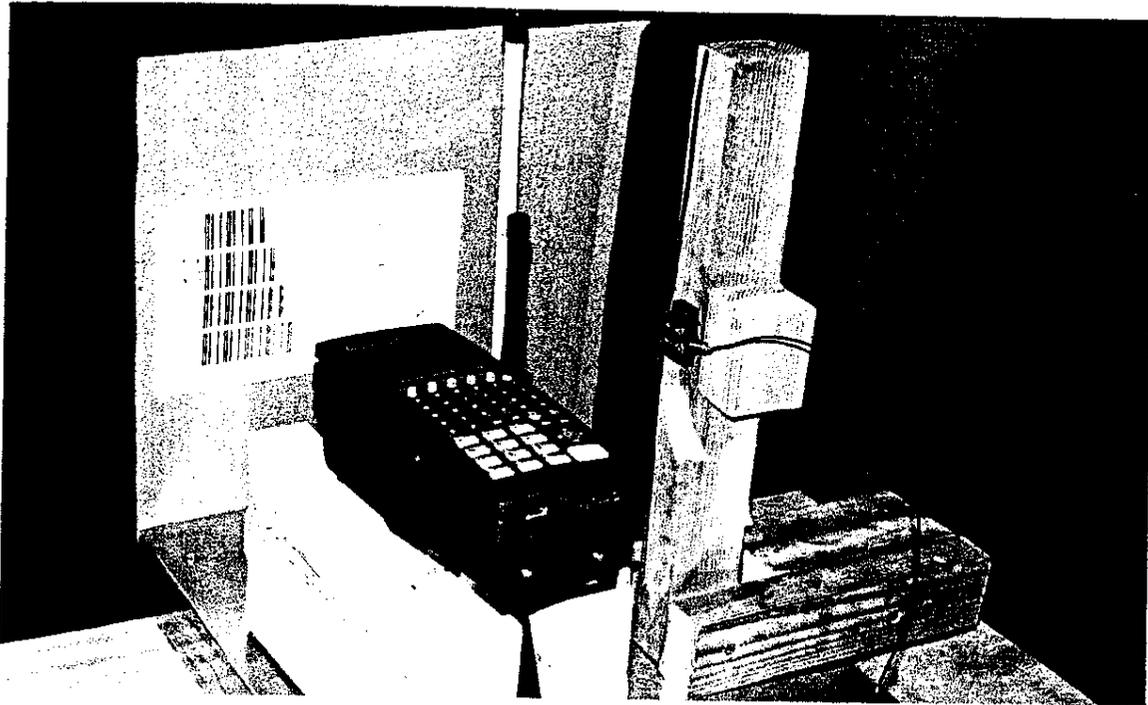


Figure 7. Antenna/EED Test Configuration.

III. TEST METHODOLOGY

1. RE102 Tests: The Savi GateReader 410R Controller and Fiber Optic Router were placed in the Equipment Under Test (EUT) screen room, while the rest of the system was operated outside the screen room. The Savi GateReader system was triggered by placing an operating electric fan in front of the vehicle motion sensors. For these efforts the Radiated Emissions (RE) from Savi GateReader 410R Controller and Fiber Optic Router were measured in the frequency range of 10 kHz to 1GHz.

2. Output Signal Spectrum Analysis: For these efforts, the hand held interrogators, and measuring equipment configuration were as described in paragraph II.2. All losses in the measurement system equipment setup, such as cable, connectors, and connector adapter losses were determined and recorded prior to making any measurements. This was accomplished by substituting a HP8648D RF Signal Generator for the hand held interrogators, as the RF signal source, and measuring the loss resulting from all interconnecting cables and connectors to be used between the receive antenna and the HP 8566B spectrum analyzer.

The AIT equipments subjected to this analysis were operated, for comparison purposes, in the same manner as they were during the test efforts of July and August 1997. The hand held interrogators, when "triggered", were found to increase their output signal level

failed. Therefore, during these efforts, the SaviTags were not turned on, in order to acquire the highest possible output signal levels from the hand held interrogators.

3. EED Investigation: For these efforts the antennas/EEDs were placed on the Antenna Fixture, four (4) inches from the RF source antenna, which was driven by a HP 83732A signal generator. We found the most sensitive antenna/EED configuration to be with the dipole antenna. We then evaluated six (6) EEDs with the dipole antenna, and found the most sensitive antenna/EED configuration to be the dipole antenna with an S75 EED (S/N 14657).

The dipole antenna, with an S75 EED, was placed on the Antenna Fixture at a distance of four (4) inches from the Savi MobileReader 410R antenna. The 410R was programmed to operate as delineated in paragraph II.2. above, and the effects on the EED were monitored by the Metricor recorder/plotter, which was isolated from the EM environments in a shielded room.

IV. TEST RESULTS AND DISCUSSION

1. RE102 Test Results

a. Savi GateReader 410R: The Savi GateReader 410R Prototype Controller, and the Fiber Optic Router, with associated cables were the only AIT items subjected to RE102 tests and evaluations during these efforts.

b. When measured from a distance of one meter, the radiated emissions from the Savi GateReader 410R Controller and Fiber Optic Router exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 45 MHz to 930 MHz. The highest level of Radiated Emissions (RE) was found to be 40 dBuV/m [or 16 dBuV/m above the acceptable RE102-2 limits of reference (a)] recorded at a frequency of 90 MHz. Plots of the measured Radiated Emissions from the Controller and Fiber Optic Router, as tested, are provided in Attachment (2).

c. The results of these tests should be considered in determining a suitable location for the use of the equipments based on: (1) the effect that the RE from each unit tested may have on sensitive electronic equipments located in close proximity to them; and (2) the sensitivity of the information being processed by, or passing through the units. The results could also be considered as a guide in determining the potential risk for HERO problems resulting from the in-band and out-of-band radiated emissions from operating units.

d. During discussions with the Savi on-site personnel, we were informed that the Router had not yet completed FCC tests.

2. Output Signal Spectrum Analysis Results

a. Savi MobileReaders 410R, Mod. #SMR-410R-200, [Serial Number 98020400443 (Unit #1), Serial No. 98020400432 (Unit #2)] Hand held Bar Code Reader/RF Interrogator w/RF Identification (RFID) only @ 433.92 GHz: During the July 1997 tests and evaluations, the output signal levels of all of the hand held interrogators were found to be from 95.9 dBuV to 116.3 dBuV, when measured at a distance of 12 inches. However, in March 1998 the output signal of this unit was found to have been reduced to a level of 87.92 dBuV, when measured at a distance of four (4) inches, at 433.845 MHz. The 433.845 MHz signal is continuously transmitted for a period of 2.6 seconds each time the transmit section of the unit was activated, and is not adjustable. The output signal spectrum characterization of Unit #1 is presented in plot #032498-001 in Attachment (3).

b. As a part of this effort, we attempted to evaluate the effectiveness of the Savi output signal level control program, which was used to set the output signal level of the RFID units. The output signal level control program is considered "firmware", which according to the Savi on-site representative will be loaded on an EPROM in the RFID unit by Savi, and will not be sold or distributed with the units.

During the evaluation of the "firmware" in unit #1, we found that changing the program parameters to reduce the output signal level sometimes had no effect on the output level, or the opposite effect. After expending a considerable amount of time and effort: to modify the program; change out the EPROM; swap the "COMM" board between Units #1 and #2; install new "COMM" boards; and evaluate the effect of each modification and change; we were informed by the Savi representative that both units were defective. Therefore, these tests and evaluations were discontinued.

c. Savi MobileReader 410R, Mod. #SMR-410R-200, Serial Number 98032400481 (Unit #3) Hand held Bar Code Reader/RF Interrogator w/RF Identification (RFID) only @ 433.92 GHz: During the period of 26-29 May, the handheld interrogator designated as Unit #3 was evaluated. This unit was thoroughly tested at Savi to ensure that the output signal level control program, and "Comm" board functioned properly, before the unit was shipped for test and evaluation.

The operation of the Savi MobileReader 410R designated as Unit #3 verified that the "Firmware revision 3.76" output signal level adjusting program adequately controls the interrogator output signal level. During these tests and evaluation, the output signal level control program (Savi Firmware revision 3.76) could reliably be set to maintain the output signal level of the hand held interrogator/transmitter at the Army's 87 dBuV requirement. With a fresh battery installed in Unit #3, and the output signal level

control set at: 56 for the "Wakeup" signal; 86 for the "Control" signal; and 84 for the "Data" signal; the maximum output signal level was found to be 86.87 dBuV at 432.90 MHz. The output signal spectrum characterization of Unit #3 is presented in plot #052798-006 in Attachment (3).

d. SaviReader 410R - Fixed location RF Interrogator. Model #410R-001, Serial No. 2014, and Model # SR410R-006 S/N 3803: On 25 March 1998, the output signal level of the SaviReader 410R, Model # 410R-001, S/N 2014 was found to be a maximum of 82.08 dBuV at a distance of 24 inches, with the mounting surface of the antenna/transceiver module oriented in a horizontal polarization relative to the measuring antenna. In the vertical polarization, the output signal level was found to be 66.87 dBuV at 24 inches, with the highest signal levels of 69.03 dBuV measured at a distance of 48 inches. The output signal spectrum characterization of this unit is presented in plots #032598-008, #032598-004 and #032598-005 in Attachment (3).

However, we were later informed by the Savi representative that upon return of this unit to Savi, they discovered that not all of the antenna elements in the unit were connected. Therefore, the unit would require retesting in May.

For the May 26 retest, the vendor supplied a SaviReader 410R Model SR410R-006 S/N 3803. The maximum output signal level emitted by this unit, when mounted in a vertical orientation relative to the measuring antenna, was 89.56 dBuV at a distance of 24 inches. However, when mounted in a horizontal orientation, the maximum output signal level was 83.09 dBuV at a distance of 24 inches. The output signal spectrum characterization is presented in plots #052698-002 and #052698-006 respectively in attachment (3).

e. Savi GateReader 410R (RF Gate Sensor/Interrogator/Checkpoint Tracking System): The output signal levels of the Savi GateReader antenna/transceiver modules were measured to determine the safe separation distances from these units for ordnance.

The 2.4 GHz "Primary Wakeup" Antenna/Transmitter (Model Number SRA-GR-201, S/N 2804) module was found to be actually transmitting at 2.442 GHz, with measured output signal levels of 60.06 dBuV at a distance 24 inches, 62.75 dBuV at 36 inches, and 50.74 dBuV at 48 inches. The output signal spectrum characterization of this unit is presented in plots #032498-005, #032498-004, and #32498-006 respectively in Attachment (3).

The 433 MHz transceivers were found to be actually operating at 432.932 MHz, with an output signal level of 75.13 dBuV measured at a distance of 36 inches, and 80.52 dBuV measured at a distance of 24 inches. The output signal spectrum characterization of this unit is presented in plots #032598-001 and #032598-002 respectively in Attachment (3).

f. SaviTag 410 - RF Identification Device.

(Model #ST-410-118, Serial No. 0011412): The "redesigned" SaviTag 410 was not available for evaluation during the test efforts of 25 March through 4 April. However, the unit was available for test and evaluation on 26 May 1998. The output signal level of the "redesigned" SaviTag was found to be 86.84 dBuV at a separation distance of 4 inches from the measuring antenna. The output signal spectrum characterization of this unit is presented in plot #052698-008 in Attachment (3).

3. EED Investigation Results

a. The EEDs used for this evaluation were all 94 to 100 milli-amp MNFC devices. It should be understood that they do not represent the most sensitive EEDs in the Army (or Navy) inventory, however, we were able to use them to determine the signal level required to induce approximately 15 percent of the MNFC in 30 mA, 50 mA, and 100 mA devices. The EEDs evaluated, and the signal levels required to induce a given current (from 4mA to 18.5mA) in the EEDs were as presented in Table 1 below.

Table 2. Signal level required to induce 4 to 18.5 mA in the listed EEDs.

EED/Ser. #	4mA	7mA	15mA	18.5mA
S75 (14657)	97.51dBuV	103.93dBuV	110.49dBuV	112.37dBuV
S75 (16212)	98.17dBuV	102.09dBuV	110.05dBuV	
T20E1(15493)	99.87dBuV	105.09dBuV	111.07dBuV	
S75 (14964)	101.41dBuV	104.57dBuV	110.29dBuV	
MK71 (16948)	100.51dBuV	105.19dBuV	111.83dBuV	
MK71 (16957)	101.43dBuV	107.07dBuV	112.07dBuV	

b. Since some EEDs may have a "Maximum No Fire Current" (MNFC) of as low as 30 mA, it is essential that the MNFC, or MNFS of ordnance in the area be given due consideration before operating any electronic/electrical equipment, or intentional transmitter in close proximity of ordnance. If this information is unknown at the time of the operation, it should be assumed that the ordnance in the inventory area contains the most sensitive EED (lowest maximum no fire current or MNFS) in use.

V. RECOMMENDATIONS

1. These recommendations are made as a consequence of the RE102 test results, output signal spectrum analysis, and the EED investigations. The recommendations for each item tested are presented individually, as follows:

(a) Savi GateReader 410R - In light of the RE102 test results, we recommend the following:

(1) that the "as tested" configuration of the Savi GateReader 410R Controller be considered a "Prototype" rather than a final production unit; and

(2) if the Controller and Fiber Optic Router are mounted in the same enclosure, the configuration should be retested; or

(3) care must be taken to ensure that the Controller/Fiber Optic Router configuration are not operated within one (1) meter of other sensitive electronic equipment, or ordnance.

(b) Savi MobileReader 410R, Mod. #SMR-410R-200 - An antenna test fixture, identical to the one used during output signal level analysis, has been provided to Savi to aid them in setting the output signal level of the Savi MobileReaders. Therefore, once set to the Army's specified maximum output signal level at the factory, by Savi, the MobileReaders should not present a hazard to ordnance when operated at a distance of four (4) inches or more from ordnance. However, it is important to ensure that the interrogators contain freshly charged batteries when the output levels are set, and there should be no operating SaviTags in the area.

(c) SaviReader 410R - Fixed location RF Interrogator. Model #410R-001, and Model # SR410R-006 - The test results indicate that the interrogators, as tested, should not present a hazard to ordnance when mounted in such a manner as to maintain a separation distance of greater than 24 inches from ordnance.

(d) Savi GateReader 410R Transceiver/Antenna Modules - In light of the Output Signal Spectrum Analysis of the Transceiver/antenna modules, we recommend that both the 433 MHz antenna/transceiver modules and the 2.4 GHz "Primary Wakeup" Antenna/Transmitter (Model Number SRA-GR-201, module be considered as not presenting a hazard to ordnance when operating at a distance of 24 inches.

(e) SaviTag 410 - RF Identification Device (Model #ST-410-118) - The "newly designed" SaviTag should not be considered as presenting a hazard to ordnance when mounted in such a manner as to maintain a minimum separation distance of four (4) inches from the ordnance.

2. Based on the results of our EED investigations, the Army's maximum allowable signal output level of 87 dBuV could be increased. However, when the output signal level is checked at the factory, a Savi MobileReader with a faulty or moderately discharged battery could easily indicate a signal output level of 3 dBuV lower than it would have with fresh, fully charged battery. Therefore,

we highly recommend that if the Army's maximum allowable signal output level is increased, it should be limited to no higher than 90 dBuV.