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U.S. ARMY LOGISTICS INTEGRATION AGENCY
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ALEXANDRIA, VIRGINIA 22333-0001

LOIA-LS

19 FEB 1998

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Safety Evaluation For Ammunition Automatic Identification Technology (AIT) Integration

1. References:

a. 27 Jan 98 Hazards of Electromagnetic Radiation to Ordnance (HERO) Safety Meeting.

b. 10 Feb 98 Follow-on HERO Safety Meeting.

2. The Logistics Integration Agency is implementing an AIT pilot program that streamlines and automates ammunition support processes from wholesale through transportation to retail supply. Advanced radio frequency identification and tracking technology will be used to facilitate ammunition process improvements.

3. As part of the ammunition AIT integration effort, the Naval Surface Warfare Center, Dalgran Division (NSWCDD) conducted a HERO Safety Evaluation to test radiated emissions and susceptibility of AIT equipment. For information purposes, NSWCDD test results and recommendations are enclosed.

4. The SAVI Tag 410 tested is considered safe around ammunition per reference a. Other equipment radiated emissions at a level to be concerned about in the close proximity of unshielded ordnance. A follow-on meeting, reference b, has been conducted at the NSWCDD to address remaining issues. Based on the AIT's intended use, a course of action has been established to resolve remaining issues through policy, doctrine, training, equipment re-design, and follow-on testing.

5. My POC for this action is Mr. John Waddick, DSN 767-4494 or COMM (703) 617-4494.

Encl

MELANIE A. HUGHES
Chief, Logistics Systems Division

LOIA-LS
SUBJECT: Safety Evaluation For Ammunition Automatic Identification Technology (AIT) Integration.

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INTERMEC CORPORATION, ATTN: MR. GEORGE MOSS
SAVI TECHNOLOGY, ATTN: VERMA VIKRAM

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

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

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

August 1997

HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO) SAFETY EVALUATION AND RADIATED SUSCEPTIBILITY TESTS OF 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) Test Plan for the Army's Automatic Identification Technology (AIT) Ammo Tracking Equipment

I. GENERAL:

1. During the period of 08 July through 16 August 1997, Radiated Emissions (RE102), and Radiated Susceptibility (RS103) tests, as specified in the requirements and procedures delineated in references (a) and (b), were conducted on the US Army's Ammo AIT equipments. The RE102 tests were conducted as a means of evaluating the safety of using the AIT equipments in close proximity to ordnance, and other sensitive electronic equipments. The RS103 tests were conducted on specific items of the AIT equipment, which could potentially accompany, and be used to inventory Army ammunition and ordnance in close proximity of Army fix/mobile communications or radar equipments and/or aboard Navy ships. The tests were conducted in accordance with reference (c), which is included as attachment (1) for information purposes.

2. The hand held interrogators are transceivers, which are intended for use in close proximity to ordnance items. Therefore, we considered it essential that an additional analysis be performed to determine their output signal spectrum characteristics at a distance which represented the distance at which these AIT units would most likely be used to: **(a)** scan a bar code label and transmit data to a repeater or base station radio receiver; or **(b)** scan a bar code label and "write" the data to a SaviTag using the on-board transmitter of the hand held interrogator.

3. The AIT equipments evaluated were as follows:

a. SaviTag 410 - battery powered RF identification device. Model #410, S/N 10073, 10086, 10088, 10094, and S/N 10105

b. SaviReader 410R - Fixed location RF Interrogator. Model #410R-001, S/N 2014

c. SaviReader 410GR - RF Gate Sensor/Interrogator/Checkpoint Tracking System. (See Paragraph IV.1.c for Model/Serial Numbers.)

d. Intermec JR2020 - Hand held RF Data Collection (RFDC) Computer. Model #JR2020D3011002, S/N 97032600336

e. Intermec JBD202 - Hand held Data Collection Computer/RF

Interrogator Device (RFID). Model # JBD202A21150, S/N10007

f. Intermec JGD202 - Hand held Data Collection Computer/RF Interrogator w/RFDC Transceiver. Intermec Model #JGD202A2115004, S/N 10040 (2.402 - 2.480 GHz) Savi Model # SMR-410R-202 (433.8 MHz)

g. Intermec JRD202 - Hand held Data Collection Computer/RF Interrogator w/RFDC Transceiver. Intermec Model # JRD202A211502, S/N 10020 (433.92 MHz) Savi Model # SMR-410R-201

h. Intermec JRD202 - Hand held Data Collection Computer/RF Interrogator w/RFDC Transceiver. Intermec Model #JRD202A211503, S/N 10030 - (GR) (925.6 MHz) Savi Model # SMR-410R-201-G

i. Utilicom LongRanger 2000/ISM900-1HD - 900 MHz RF Modem Model #2000/ISM900-1HD, S/N 2807-736/737

j. Utilicom LongRanger 2000/ISM2.4-1HD - 2.4 GHz RF Modem Model #2000/ISM2.4-1HD S/N 2102-721/724

k. FreeWave - (1 Watt, 900 MHz) RF Transceiver (Modem) Model # DGR115H, S/N 571-1933

l. FreeWave - (5 Watt, 900 MHz) RF Transceiver (Modem) Model # DGR115, S/N 571-1935

m. Intermec - RF Controller - Model # 9180C, S/N 95062000100

n. Intermec - Base Station Radio Unit (BRU) Transceiver Model # 9181CT02 BRU S/N 95121802021 (906 - 924 MHz)

o. Intermec - RF Repeater Model 9183C02, S/N 95032901656 (906 - 924 MHz)

p. Intermec - Access Point 0110 - 2.4 GHz RF Modem Model #8600.0112.05, S/N 0110-65200514-71000157

q. Intermec - Base Station (925.6 MHz) Transceiver Model # 9181CT03-(GR), S/N 97071654321

r. Intermec - RF Repeater, Model #9183CT03, (925.6 MHz) S/N - 97071412345

II. TEST CONFIGURATION:

1. RE102 Test Configuration: Since the AIT equipments were either hand held units, or equipment not intended to be securely mounted in a specific location, 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. Those equipments that operate as a system (such as the SaviReader 410GR Gate/Checkpoint tracking system) were evaluated as a system. The test configuration of some of the AIT equipment tested are shown in figures 1 through 5.

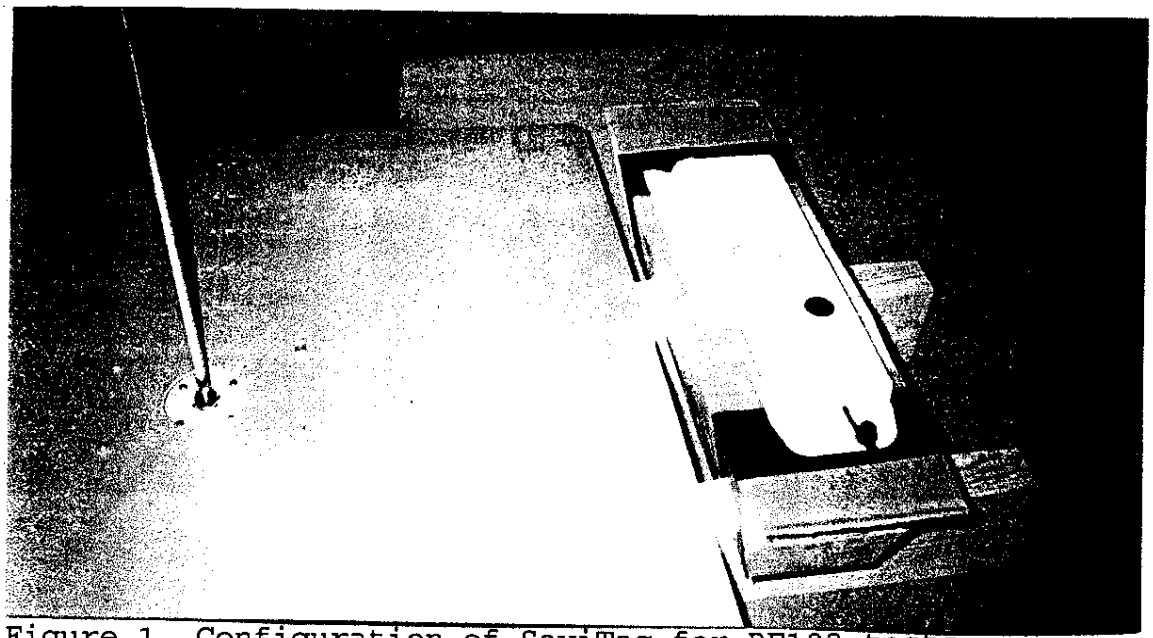

Figure 1. Configuration of SaviTag for RE102 tests.

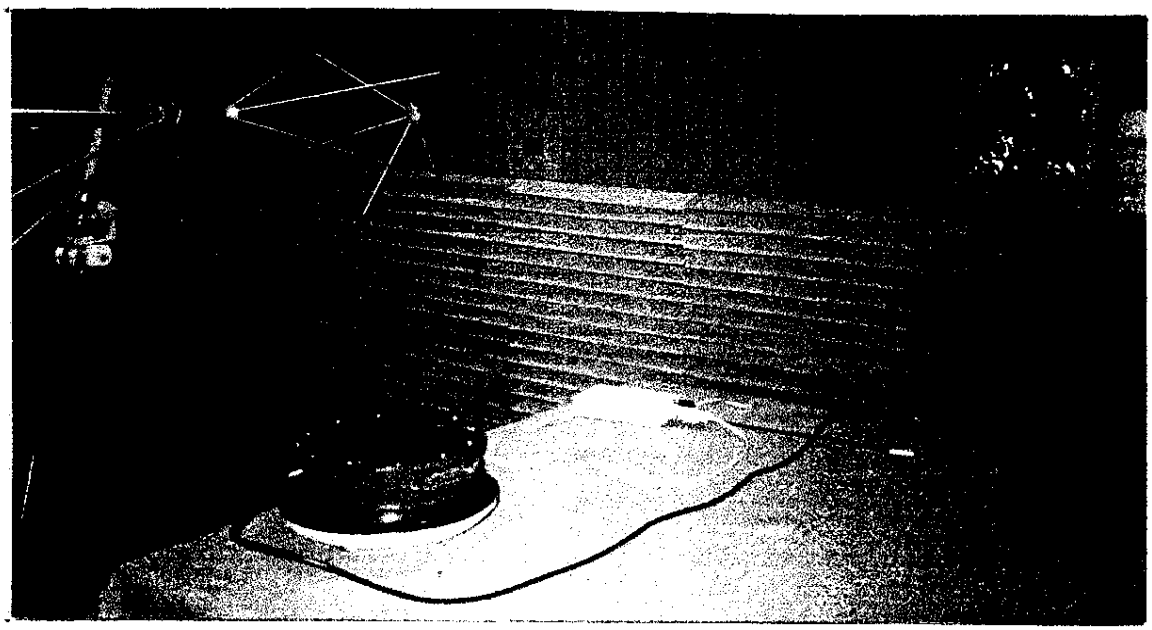

Figure 2. Configuration of SaviReader 410R for RE102 test.

AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT) EQUIPMENTS

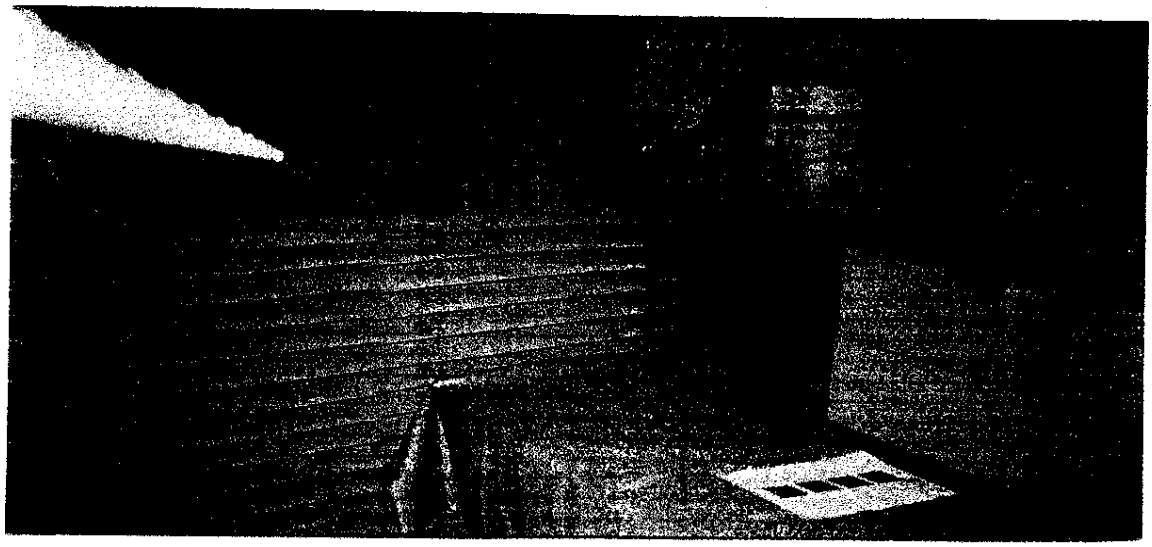

Figure 3. RE102 configuration for the Hand held interrogators.

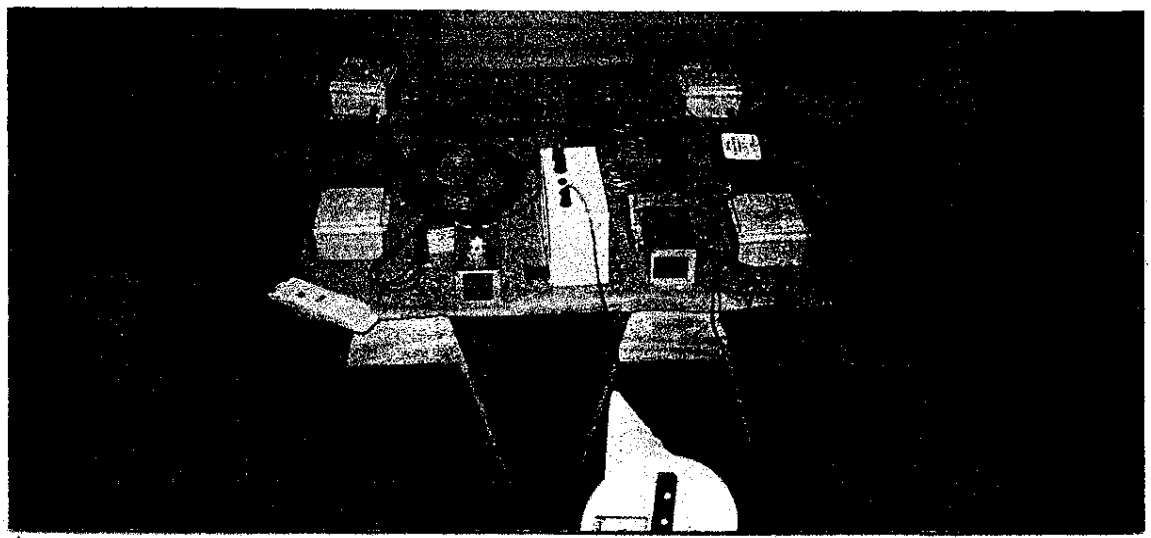

Figure 4. RE102 configuration for the SaviReader 410GR System.

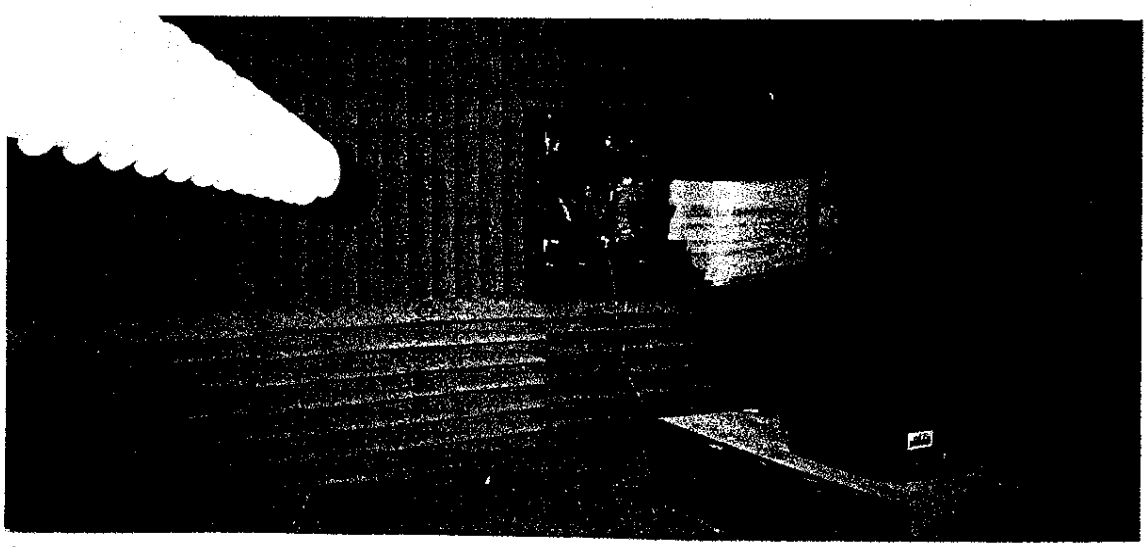

Figure 5. RE102 configuration for the Base Station Radio.

2. RS103 Test Configuration: Only those AIT equipments identified as having the potential of being used in close proximity to Army Fixed/Mobile radar or communications equipment, and/or Navy shipboard or pierside areas, were subjected to Radiated Susceptibility (RS103) tests and evaluation. The RS103 tests and evaluation were conducted to the requirements of reference (a), and in a manner which satisfied the intent of reference (b). The RS103 field intensity levels to which these equipments were tested are specified in reference (c). An example of a typical RS103 test configuration is shown in Figure 6.

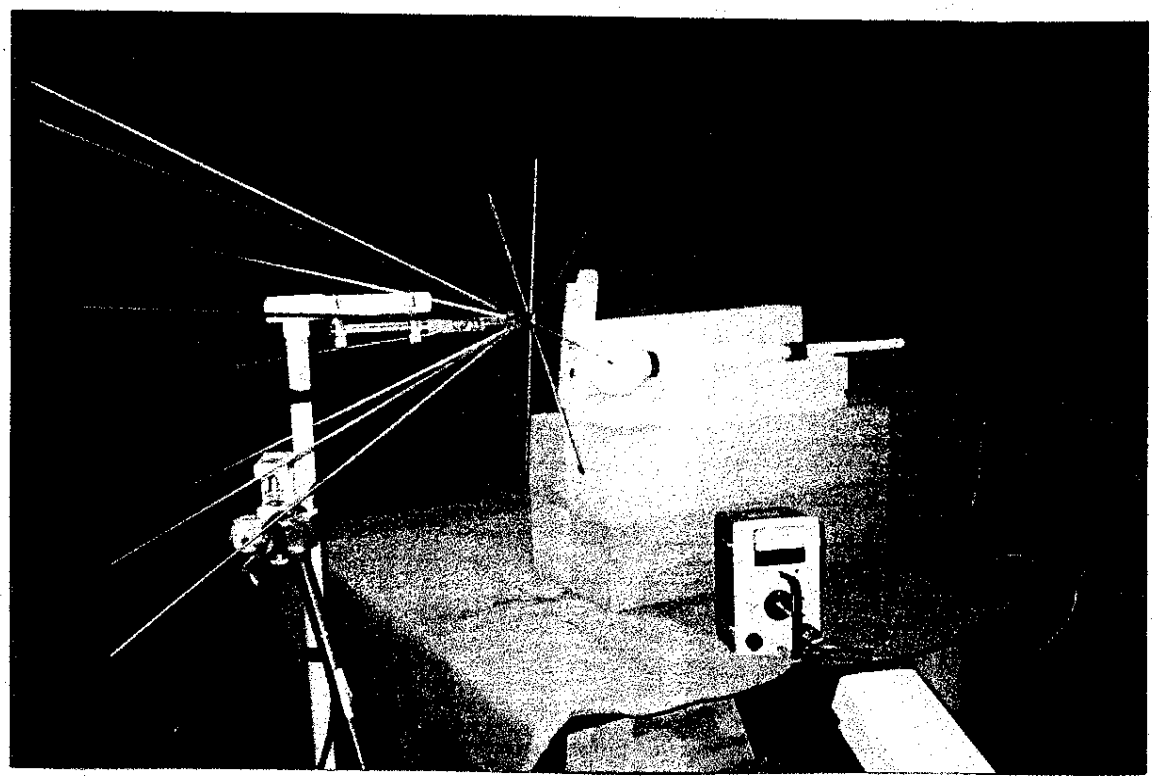

Figure 6. RS103 test configuration for the SaviTag.

3. Output Signal Spectrum Analysis Configuration: This analysis was limited to the hand held interrogators. Therefore, the construction of a special antenna test fixture to facilitate an analysis of the output signal spectrum characteristics of these units was required. The fixture, here-in-after referred to as OSSA fixture, consisted of two matched, in band 6.5 inch helical antennas mounted on a barrier plate, with an antenna separation distance of 12". The OSSA fixture was mounted in the wall between the shielded anteroom and the shielded EUT test chamber. The equipment was configured with the hand held interrogator in the anteroom, with it's RF output port connected to one of the OSSA fixture antennas via low loss cable. The OSSA fixture antenna designated as the receive antenna was coupled to a HP8566B Spectrum Analyzer via low loss cable. The OSSA fixture, as installed, is

shown in figure 7, and a typical configuration for analysis of the hand held interrogators is shown in figure 8.

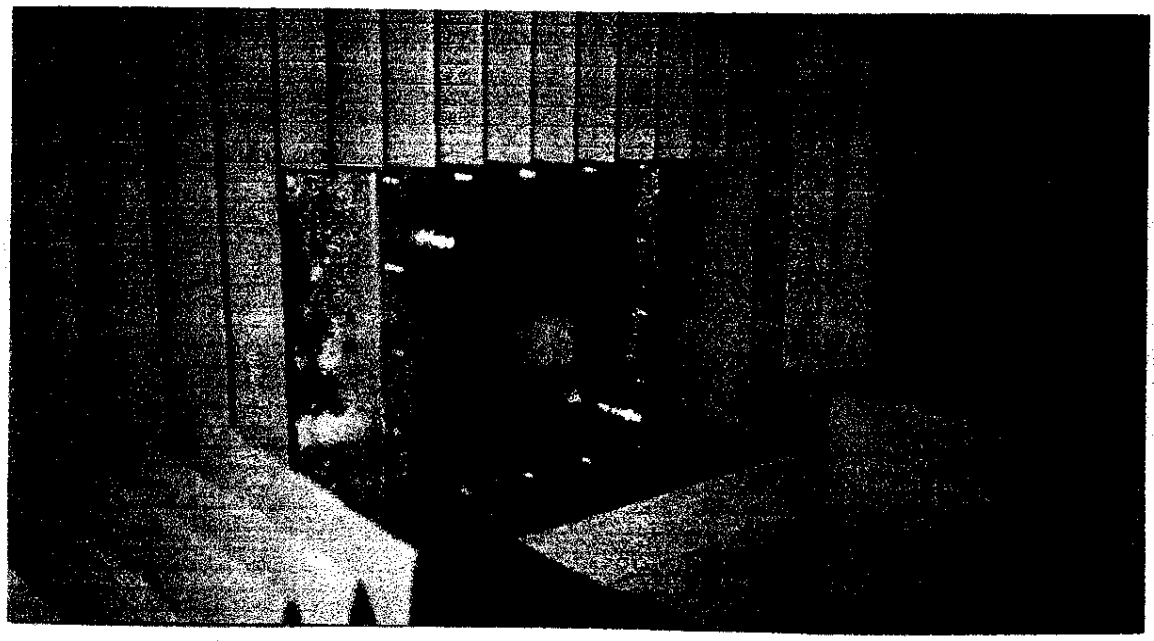

Figure 7. OSSA antenna fixture.

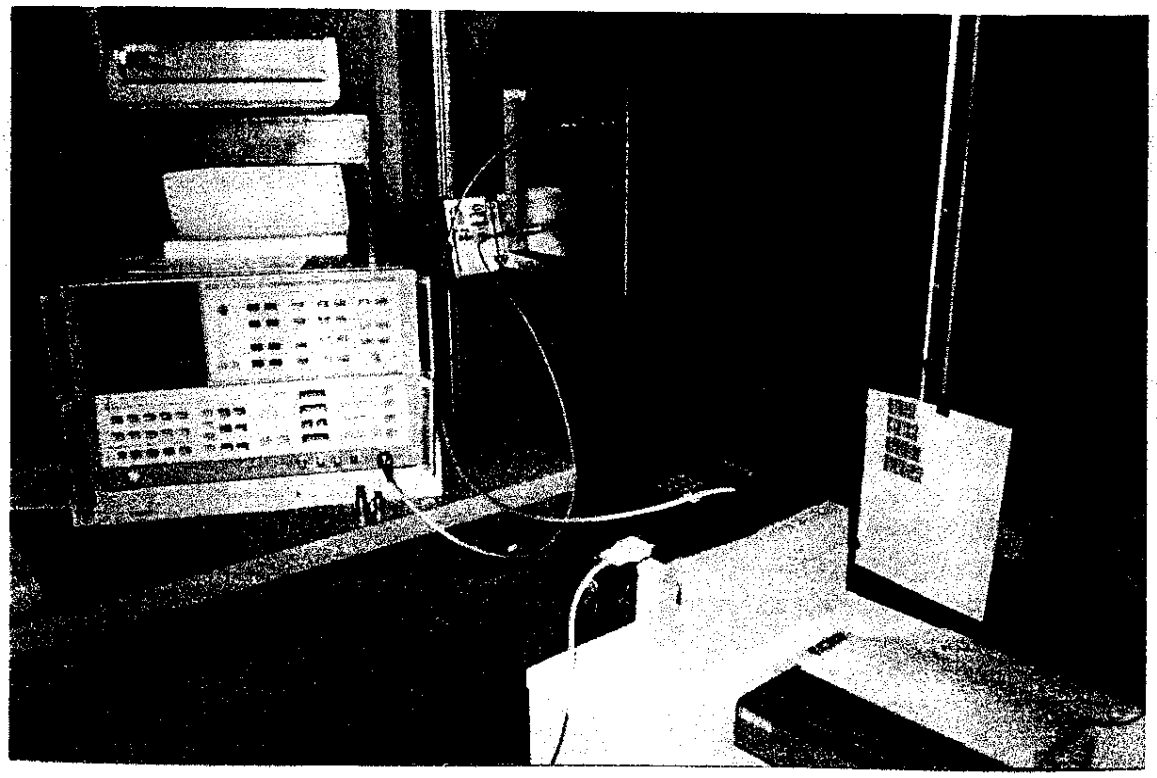

Figure 8. Typical configuration for hand held interrogators to scan bar code, and transmit via the OSSA fixture antenna.

III. TEST METHODOLOGY:

1. RE102 Tests: For these tests and evaluations, the hand held AIT equipments were either operated by test personnel, configured to run a "loop" [i.e. receiving data from the Base Station Radio Unit (BRU) and transmitting it back], or programmed to acquire the data in the memory of a SaviTag or printed on a bar code label and transmit the data to the BRU. To establish the required RF communications path between the Equipment Under Test (EUT) and the AIT equipment outside the shielded EUT test chamber, a small access port was opened in the wall of the EUT test chamber. The receive antenna of the AIT equipment outside the EUT test chamber was then placed near, or partially through the access port, as necessary. In some cases the path for communications between the hand held interrogators and the EUT was accomplished via the OSSA fixture. Those equipments that operate as a system (such as the SaviReader 410GR Gate/Checkpoint tracking system) were evaluated as a system.

2. RS103 Tests: For these tests and evaluations, a fixture was fabricated to support the hand held interrogators, and fitted with a solenoid to activate the trigger of the interrogator. During the tests, the hand held units were either activated by the solenoid, operated manually, or programmed to operate in a "loop" mode. The method of providing the necessary RF communications path between the EUTs and the AIT equipment located outside the shielded EUT test chamber was the same as that described above for the RE102 tests. Care was taken to ensure, to the extent possible, that the AIT equipment located outside the access port was not affected by the EM environment developed in the shield EUT test chamber.

3. Output Signal Spectrum Analysis: For these efforts, the hand held interrogators, and measuring equipment configuration were as described in paragraph II.3. All losses in the measurement system equipment setup, such as cable, connectors, and connector adapter losses, were calibrated out prior to making any measurements. This was accomplished by substituting a HP8648D RF Signal Generator for the hand held interrogators, and measuring the losses resulting from all interconnecting cables and connectors to be used between the interrogators and the transmit antenna, and the receive antenna to the spectrum analyzer.

The AIT equipments subjected to this analysis were operated in the same manner as they were for the RE102 and RS103 tests. For those units which communicate at multiple frequencies, all transmit frequencies were analyzed. The AIT equipment output signals were also analyzed with the units both communicating with other AIT equipments, and being denied a communications path to other equipments. It was found that some units actually increased the amplitude of their output signals in an attempt to establish communications with the SaviTag and/or the BRU.

IV. TEST RESULTS

1. RE102 Test Results

a. SaviTag 410: When measured from a distance of one meter the radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 200 MHz to 434 MHz. At one meter, the highest level of Radiated Emissions (RE) of 59 dBuV/m [or 22 dBuV/m above the acceptable RE102-2 limits of reference (a)] was recorded at this units intended output frequency of 433.9 MHz. However, since the SaviTag is intended to be attached to ordnance shipping containers, additional RE measurements were made at distances of 12.75 inches, and approximately 4 inches. The highest RE measured at a distance of 12.75 inches was found to be 62 dBuV at 1.8 GHz, and at a distance of 4 inches, the worst case RE of 64.5 dBuV was found to be at 433.96 MHz.

b. SaviReader 410R: The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 30 MHz to 1.2 GHz. In this frequency range, the emissions levels were generally found to be 30 dBuV/m above the acceptable limits. However, the highest RE levels of 51.1 dBuV/m above the acceptable limits (or 88.1 dBuV/m) were recorded at the units intentional output frequency of 433.9 MHz.

c. SaviReader 410GR: This unit, and all of it's ancillary equipment were tested as a single unit. The system components were arranged in a configuration which placed all items at the same distance from the measurement antenna. The components of the "system" were as follows:

(1) 1 ea - SaviReader 410GR, Model #SR410GR-001, Serial #1004
(2) 4 ea - SaviReader 410GR Antennas (No Model or Serial Numbers)
(3) 2 ea - Microwave Sensors, Model # TC268, Serial #338351 and #341523
(4) 1 ea - Power Supply (No Model or Serial Number)

The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 12 kHz to 3.4 GHz. In this frequency range, the emissions levels were found to be generally up to 40 dBuV/m above the acceptable limits. However, the highest RE measurement of 87.1 dBuV/m was recorded at the units intentional output frequency of 433.9 MHz.

d. Intermec JR2020 Hand held Terminal, w/RF Data Collection (RFDC): The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 250 kHz to 6.3 GHz. In this frequency range the emissions were found to be generally up to 22 dBuV/m above the acceptable

limits. However, at the units intentional transmit frequency (906-924 MHz) the highest REs of 94 dBuV/m was recorded. Plots of the radiated emission characteristics are presented in Attachment (2).

e. Intermec JBD202 Hand held terminal w/RF Identification (RFID) only @ 433.92 MHz: The radiated emissions from this unit were measured in two configurations: (1) with the unit reading a SaviTag 410; and (2) with the unit scanning a bar code label. While reading the SaviTag, the radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency ranges of 250 kHz to 3 MHz, and 200 MHz to 2 GHz. In these frequency ranges the emissions were found to generally exceed the acceptable limits by up to 4 dBuV/m and 5 dBuV/m respectively. However, the highest RE level of 63 dBuV/m, which is 26 dBuV/m above the acceptable limits, was recorded at the units intentional transmit frequency (433.9 MHz).

When the unit was configured to scan a Bar code label, the radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency ranges of 250 kHz to 380 MHz. In this frequency range the emissions were found to be up to 16 dBuV/m above the acceptable limits. Plots of the radiated emissions characteristics are presented in Attachment (2).

It should be noted that according to the Savi and Intermec representatives, this unit is not intended to transmit the Bar code or SaviTag information to the "Host" computer. According to the Savi and Intermec representatives, this unit is intended to collect the data and download it to the "Host" computer via an optical port.

f. Intermec JGD202 Hand held terminal w/RFDC at 2.4 GHz: The radiated emissions from this unit were measured in two configurations: (1) with the unit reading a SaviTag 410; and (2) with the unit scanning a bar code label. While reading the SaviTag, the radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency ranges of 250 kHz to 30 MHz, and 200 MHz to 450 MHz. In these frequency ranges the emissions were found to be generally as high as 7 dBuV/m and 3 dBuV/m respectively above the acceptable limits. However, at the units intentional transmit frequency (433.9 MHz) the highest REs of 47.5 dBuV/m, which is 10 dBuV/m above the acceptable limits, were recorded.

When the unit was configured to scan a bar code label, the radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency ranges of 250 kHz to 200 MHz. In this frequency range the emissions were found to be up to 16 dBuV/m above the acceptable limits. Plots of the radiated emissions characteristics are presented in Attachment (2).

It should be noted that during these measurements, the 2.4 GHz

transmitter contained in the unit was not used. According to the Savi and Intermec representatives, the application software had not yet been written to allow us to exercise this function.

g. Intermec JRD202 Hand held terminal w/RFDC at 906 to 924 MHz: The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 250 kHz to 7.4 GHz. In the frequency range of 250 kHz to 300 MHz the highest emissions levels found were 18 dBuV/m above the acceptable limits. However, the RE was 95 dBuv/m at the units intentional transmit frequency of 924 MHz, and above the unit's intentional transmit frequency REs that exceeded 97 dBuV/m by a significant amount were recorded. Plots of the radiated emission characteristics are presented in Attachment (2).

In the interest of determining the level of radiated emissions that ordnance might be exposed to during actual use of this unit, the output signal level was measured at the intended transmitting frequency using a HP8566B Spectrum Analyzer, at a distance from the unit of 12 inches. The unit was found to be transmitting at 924.0 MHz, and the output signal level was measured as 126 dBuV.

h. Intermec JRD202 Hand held terminal w/RFDC @ 925.6 MHz: For these measurements, the unit was exercised by scanning a Bar code label, and transmitting the data to the "Host" computer. The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 250 kHz to 8.32 GHz. In the frequency range of 250 kHz to 1 GHz the highest emissions levels were found to be 31 dBuV/m above the acceptable limits. However, from 1 GHz to 8.32 GHz the REs were found to be as high as 97 dBuV/m, which is as much as 45 dBuV/m above the acceptable limits. Plots of the radiated emission characteristics are presented in Attachment (2).

i. Utilicom LongRanger 2000/ISM900-1HD - 900 MHz RF Modem Model #2000/ISM900-1HD: The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 550 kHz to 1 GHz. In the frequency range of 550 kHz to 900 MHz, excluding the intended operating frequency of the unit, the highest emissions levels found were 40 dBuV/m above the acceptable limits. The RE level was found to be 73 dBuV/m at the units intentional transmit frequency of 906 MHz. Plots of the radiated emission characteristics are presented in Attachment (2).

j. Utilicom LongRanger 2000/ISM2.4-1HD - 2.4 GHz RF Modem Model #2000/ISM2.4-1HD: The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 550 kHz to 2.5 GHz. In this frequency range, excluding the intended operating frequency of the unit, the highest emissions levels found were 39 dBuV/m above the acceptable limits. The RE level was found to be 71 dBuV/m at the units intentional transmit frequency of 2.5 GHz. Plots of the radiated emission

characteristics are as presented in Attachment (2).

k. FreeWave - (1 Watt, 900 MHz) RF Transceiver (Modem) Model #DGR115H: The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 35 MHz to 1.9 GHz. In this frequency range, the highest emission levels recorded were 29 dBuV/m above the acceptable limits. Plots of the radiated emission characteristics are as presented in Attachment (2).

l. FreeWave - (5 Watt, 900 MHz) RF Transceiver (Modem) Model #DGR115: The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 400 kHz to 2.3 GHz. In this frequency range, excluding the intended operating frequency of the unit, the highest emission levels recorded were 36 dBuV/m above the acceptable limits. The RE level was found to be 70 dBuV/m at the units intentional transmit frequency of 2.5 GHz. Plots of the radiated emission characteristics are as presented in Attachment (2).

m. Intermec - RF Controller - Model #9180C: The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 320 kHz to 1.9 GHz. In this frequency range, excluding the intended operating frequency of the unit, the highest emission levels recorded were 54 dBuV/m above the acceptable limits. The RE level was found to be 57 dBuV/m at the units intentional transmit frequency of 924 MHz. Plots of the radiated emission characteristics are presented in Attachment (2).

n. Intermec - Base station Radio Unit (BRU) Transceiver Model #9181CT02 BRU (906-924 MHz): The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 650 kHz to 9.25 GHz. In this frequency range, excluding the intended operating frequency of the unit, the highest emission levels recorded were 40 dBuV/m above the acceptable limits. The RE level was found to be 88 dBuV/m at the units intentional transmit frequency of 923 MHz. Plots of the radiated emission characteristics are presented in Attachment (2).

o. Intermec - RF Repeater Model #9183C02 (906-924 MHz): The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 240 kHz to 8.3 GHz. In this frequency range, excluding the intended operating frequency of the unit, the highest emission levels recorded were >40 dBuV/m above the acceptable limits. The RE level was found to be 95 dBuV/m at the units intentional transmit frequency of 924 MHz. Plots of the radiated emission characteristics are presented in Attachment (2).

p. Intermec - Access Point 0110 - 2.4 GHz RF Modem Model #8600.0112.05: The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the

frequency range of 50 kHz to 7.3 GHz. In the frequency range of 50kHz to 7.3GHz, with the exception of the units intended operating frequency, the highest emissions levels found were 40 dBuV/m above the acceptable limits. However, the RE was found to be 96 dBuV/m at the units intentional transmit frequency of 2.5 to 2.6 GHz. Plots of the radiated emission characteristics are presented in Attachment (2).

q. Intermec - Base Station Transceiver (925.6 MHz) Model #9181CT03-(GR): The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 180 kHz to 9.3 GHz. In the frequency range of 180 kHz to 1 GHz, excluding the intended operating frequency of the unit, the highest emissions levels found were 36 dBuV/m above the acceptable limits. The RE was found to be 35 dBuV/m at the units intentional transmit frequency of 925.6 MHz. However, in the frequency range of 1 GHz to 9.3 GHz the emissions were found to be as high as 109 dBuV/m. Plots of the radiated emission characteristics are presented in Attachment (2).

r. Intermec - RF Repeater - Model #9183CT03-(GR): The radiated emissions from this unit exceeded the acceptable RE102-2 limits of reference (a) in the frequency range of 280 kHz to 9.3 GHz. In the frequency range of 180 kHz to 1 GHz, excluding the intended operating frequency of the unit, the highest emissions levels found were 34 dBuV/m above the acceptable limits. The RE was found to be 79 dBuV/m at the units intentional transmit frequency of 925.6 MHz. However, in the frequency range of 1 GHz to 9.3 GHz the emissions were found to be in excess of 97 dBuV/m. Plots of the radiated emission characteristics are presented in Attachment (2).

2. **RS103 Test Results**

a. SaviTag 410: For these tests the SaviTags were placed in the shielded EUT room, and were exercised by a JBD202 (RFID) hand held interrogator. The hand held interrogator was setup in the shielded test facility anteroom, and programmed to: (1) read a bar code label; (2) send a "wake up" signal to the SaviTag; (3) write the bar code label data on the SaviTag; (4) read the data received and entered into memory on the Tag; and (5) printout, via an optical port adapter, the time, data written to the Tag and read back from the Tag, and pass/fail message based on a comparison of the transmitted data to the data retrieved from the Tag.

While conducting RS103 tests in the frequency range of 10MHz to 120MHz the SaviTag 410, **S/N 10094**, indicated susceptibility at 11MHz at a threshold level of 4V/m. At a field intensity of 12V/m, this SaviTag suffered severe loss of memory function. We were informed by the Savi representative that an 11MHz signal was used in the SaviTags to accomplish some type of general "housekeeping" within the tags. Each of the other four SaviTags were then

subjected to radiated RF environments at 11 MHz to determine their threshold level of susceptibility at that frequency, for comparison purposes. The serial numbers, and threshold levels (at 11 MHz) for each tag were as follows:

S/N	Threshold	S/N	Threshold
10073	23 V/m	10094	4 V/m
10086	24 V/m	10105	2 V/m
10088	14 V/m		

Reference (a) requires that the EUT pass the RS103 radiated susceptibility tests at a field intensity level of 50 V/m in the frequency range of 2 MHz to 20 GHz. Therefore, all of the SaviTags must be considered as having failed the RS103 tests at 11 MHz.

SaviTag serial **#10094** was reprogrammed by the Savi representative, using the Savi 410R, fixed location interrogator. After being reprogrammed, the RS103 tests were re-run on this Tag at 11 MHz without any indication of susceptibility. However, it should be noted that the RFID hand held interrogator was also reprogrammed to allow a much longer delay between its' functions of writing data to the Tag, and reading back the data written. This increased delay allowed the Tag to return to a "sleep" state after the data was written to its' memory.

SaviTag serial **#10088** was selected to be subjected to radiated RF environments at field intensity levels up to 50 V/m to determine the extent of its susceptibility in the 1MHz to 1 GHz frequency range. The Tag was exercised by the RFID interrogator with the programmed increased delay. The results indicated that, with the increased delay of the RFID, the SaviTag was not susceptible at 11MHz, but was still susceptible in significant portions of the 1MHz to 1 GHz frequency range at threshold levels as low as 15 V/m.

b. Intermec JBD202 Hand held terminal w/RF Identification (RFID) only @ 433.92 GHz: For these RS103 tests, the unit set up in the shielded EUT room, and was programmed to: **(1)** read a bar code label; **(2)** send a "wake up" signal to the SaviTag; **(3)** write the bar code label data on the SaviTag; **(4)** read the data received and entered into memory on the Tag. The time, data written to the Tag and read back from the Tag, and pass/fail message based on a comparison of the transmitted data to the data retrieved from the Tag were then downloaded and printed out via the unit's optical port.

Since we were unable to obtain a real time printout with the unit in this configuration, we relied heavily on the accuracy of the time indicated on the printout for the unit having written to and read the data in the tag memory. After conducting RS103 tests in the frequency range of 1MHz to 110MHz, we found that the time recorded was only the time that the unit was triggered, rather than

a "time tag" of the initiation of items (2) and (4) above as we had requested. Although some failures were indicated in the 8 MHz to 76 MHz frequency range it was not possible to accurately determine at what frequency the failures occurred from the print out.

RS103 tests of the RFID were continued after modified software was installed by the Savi representative, which placed a "time tag" as requested earlier. The RS103 tests were conducted in the frequency range of 1 MHz to 1 GHz, with failures being indicated near the intended transmit frequency of the unit in the area of 435 MHz to 445 MHz. Failures were also indicated in the 2 GHz to 4 Ghz frequency range at threshold levels of as low as 25 V/m.

Upon further examination of the data printed out, we found that the internal clock of the RFID was erratic, and gained as much as 4.5 minutes per hour. We also found that the amount of time for each cycle (i.e. from the time the unit was triggered to the time it completed the pass/fail comparison) varied from 26 seconds to 57 seconds. Since the RS103 data was not download after RF exposure at each frequency, but rather after the unit had been exposed to a band of frequencies, the erratic internal clock made it extremely difficult to identify at which frequency a failure may have occurred.

In answer to the reasons for the erratic internal clock, and the variations in the amount of time required for each cycle, the Intermec and Savi representatives responded with the following: **(1)** "New boards that they were using for the hand held units had additional capacitance that they were presently trying to compensate for. This additional capacitance affected the oscillator frequency of the on board clock;" and **(2)** "The hand held unit will transmit two wake-up signals to the SaviTag, then after writing to the Tag it will interrogate the Tag twice, waiting an unknown amount of time between each query. If there is no response from the Tag, it will go back to the processor, and the processor will tell the interrogator to try again and may tell it to try again as many as eighteen (18) times."

In light of (2) above, it is quite probable that the extent of the radiated susceptibility of the hand held interrogators was masked by the repeated attempts of the units to communicate with the Tag. For example, assuming the RFIDs ability to communicate with the SaviTag was inhibited by the RS103 test environments, and the RFID made the maximum of 38 attempts to communicate (19 cycles with 2 attempts in each cycle) with the Tag, this scenario could require a dwell time at each of the 456 discrete frequencies, necessary to thoroughly cover the 1 MHz to 10 GHz range, of 8.1 minutes. Since we were not initially informed that the hand held interrogators would continue to try as many as an additional 18 cycles to communicate with the Tags, with our limited available test time we only allowed 1 to 2 minutes (2-3 complete cycles) dwell time at each frequency.

3. **Output Signal Spectrum Analysis Results**

a. Intermec JR2020 Hand held Terminal, w/RF Data Collection (RFDC): An analysis of the output signal spectrum was conducted while the unit was configured to read a bar code label, and transmit the data to the "Host" computer. The analysis revealed that the RF output power of this unit is 8.90 dBm, or (115.9 dBuV), at 924.6 MHz, measured at a distance of twelve (12) inches from the transmit antenna. The analysis also revealed that the 924.6 MHz signal is on for a period of 1.5 seconds each time the unit is triggered. The output signal spectrum characterizations are presented in plots 97080804 and 97080804A in Attachment (3).

b. Intermec JRD202 Hand held terminal w/RFDC @ 925.6 MHz: An analysis of the output signal spectrum was conducted with the unit configured to interrogate a SaviTag at 433.833 MHz, and transmit the data to the "Host" computer at 925.8 MHz. The analysis revealed the RF output power of this unit at 433.833 MHz is 4.95 dBm, or 112 dBuV, and the transmitted signal is on the air for a period of approximately 2.5 seconds at a time. The RF output power at 925.8 MHz was found to be 9.30 dBm, or 116.3 dBuV. The RF output signals were measured at a distance of twelve (12) inches from the transmit antenna. The output signal spectrum characterizations are presented in plots in Attachment (3).

c. Intermec JBD202 Hand held terminal w/RF Identification (RFID) only @ 433.92 GHz: An analysis of the output signal spectrum was conducted with the unit configured to interrogate a SaviTag at 433.833 MHz, and down load the data to a printer via an optical port adaptor. The analysis revealed the RF output power of this unit at 433.833 MHz was -11.04 dBm, or 95.90 dBuV. Again the 433.8 MHz signal was continuously transmitted for a period of 2.6 seconds at a time. The RF output signals were measured at a distance of twelve (12) inches from the transmit antenna. The output signal spectrum characterizations are presented in plots in Attachment (3).

d. Intermec JGD202 Hand held terminal w/RFDC @ 433.8 MHz and 2.4 GHz: An analysis of the output signal spectrum was first conducted (on 07 August) with the unit configured to interrogate a SaviTag at 433.8 MHz, and down load the data to a printer via an optical port adaptor. The analysis revealed the RF output of this unit at 433.845 MHz was 95.70 dBuV, and the signal was on the air for 2.56 seconds.

On 15 August the appropriate software program was installed, and the unit was then configured to transmit data, at a frequency of 2.4 GHz, to the "Host" computer via the Intermec Access Point RF modem. The output signal level was found to be 84.9 dBuV at 2.477 GHz.

The RF output signals were measured at a distance of twelve (12) inches from the transmit antenna. The output signal spectrum characterizations are presented in plots 97080702 and 97081501 respectively in Attachment (3).

e. Intermec JRD202 Hand held terminal w/RFDC @ 433.8 MHz and 906-924 MHz: An analysis of the output signal spectrum was first conducted with the unit configured to interrogate a SaviTag at 433.8 MHz, and down load the data to a printer via an optical port adaptor. The analysis revealed that transients riding on the leading and trailing edge of this signal were as high as 3.68 dBm, or 110.7 dBuV, however, the RF output level of this unit at 433.899 MHz was 91.96 dBuV. The 433.899 MHz "wake up" signal from this unit was on the air continuously for 2.56 seconds each time the unit interrogated the SaviTag.

The Unit was then configured to read a bar code label and transmit the data, at a frequency of 906 - 924 MHz, to the "Host" computer. The power output of this unit was measured as 3.68 dBm (or 2.25 mW) at 924.2 MHz, with it's output terminal connected directly to a HP8566B Spectrum Analyzer. The output signal was found to be on for .20 seconds each time the unit was "triggered", and the output signal level was found to be 71.8 dBuV at 923.77 MHz.

The RF output signals were measured at a distance of twelve (12) inches from the transmit antenna. The output signal spectrum characterizations are presented in plots 97080704, 97080706, 97080801 and 97080803 respectively in Attachment (3).

V. CONCLUSIONS/DISCUSSION:

1. RE102 Tests - The results of these tests should be considered in determining a suitable location for the use of the equipments, based on the effect that the RE from each unit tested may have on sensitive electronic equipments located in close proximity to them. The results may also be considered as a guide in determining the potential risk of HERO problems resulting from the in-band and out-of-band radiated emissions from operating units.

2. The AIT equipments subjected to RE102 tests and evaluation were considered as being in two categories, which are: **(a)** Category 1 - those AIT equipments which are intended, or expected to be used in shipboard or dockside EM environments, or in close proximity (i.e. a distance of one meter or less) to ordnance, ordnance buildup areas, and/or ordnance storage areas; and **(b)** Category 2 - those AIT equipments which are not intended, or expected, to be operated in close proximity (i.e. at least three meters away) from ordnance, ordnance buildup areas, and/or ordnance storage areas.

a. **Category 1 Equipments** - This category includes the SaviTags, and all hand held interrogators. The radiated emissions from all units tested exceeded the acceptable RE102-2 limits of reference (a), and most of the units exceeded these limits by a considerable amount. Conclusions based on the test results for the SaviTags and those for the hand held interrogators are addressed separately as follows:

1. The radiated emissions from the SaviTag were at a relatively low level. Therefore, it is considered unlikely that the levels of radiated emissions measured from the SaviTag will have a detrimental effect on ordnance, or the electro-explosive devices (EED)s used in ordnance. Ordnance items which are within closed metallic shipping containers will be afforded an additional margin of safety.

2. The radiated emissions measured from the hand held interrogators were of a level which could induce a significant amount of current into a 3 ohm EED, assuming perfectly coupling at a distance of 1 meter. However, these units