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IN REPLY REFER TO

8020

Ser Q52/2250

18 MAY 2012

From: Commander, Dahlgren Division, Naval Surface Warfare Center
To: Chief Executive Officer, Visible Assets, Inc. (Stevens),
Stratham, NH

Subj: HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE SAFETY
EVALUATION TEST REPORT FOR NEAR-TOUCHING USE OF THE RUBEE
(IEEE 1902.1) BASE STATIONS WITH RANGER ANTENNA, 1T TAGS,
AND pRAP READER IN PROXIMITY TO HERO UNSAFE/UNRELIABLE
ORDNANCE

Ref: (a) Visible Assets e-mail memo Mr. J. Stevens of
25 Mar 11
(b) Funding Document No. N0017811WFO0011
(c) NAVSEA OP 3565/NAVAIR 16-1-529, Volume 2, Eighteenth
Revision of 1 Apr 11
(d) NAVSEAINST 8020.7D of 1 Aug 08

Encl: (1) Hazards of Electromagnetic Radiation to Ordnance
Safety Evaluation Test Report for Near-Touching Use
of the RuBee (IEEE 1902.1) Base Station with Ranger
Antenna, 1T Tags, and pRap Reader in Proximity to
HERO UNSAFE/UNRELIABLE ORDNANCE of May 12
(2) Hazards of Electromagnetic Radiation to Ordnance
Safety Evaluation Test Plan for Near-Touching Use of
the RuBee (IEEE 1902.1) Base Station with Ranger
Antenna, 1T Tags, and pRap Reader in Proximity to
HERO UNSAFE/UNRELIABLE ORDNANCE of Nov 11

1. As requested by reference (a) and funded by reference (b), a Hazards of Electromagnetic Radiation to Ordnance (HERO) safety evaluation test of the RuBee base stations with Ranger antenna, 1T tags, and pRap reader was conducted in November 2011 at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), Electromagnetic Environmental Effects Assessment and Evaluation Branch (Q52), Dahlgren, Virginia. The evaluated RuBee system consists of the RuBee (IEEE 1902.1) base stations [Blaster (Base-110) and Sidewinder (SW-121)] with Ranger antenna (RP-A351), 1T tags (TID-100-W-1T-S), and pRap reader (PRP-100). The purpose of this HERO safety evaluation test was to determine

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if a zero safe separation distance from HERO UNSAFE/UNRELIABLE
ORDNANCE as defined in reference (c) can be achieved during
operational use of the RuBee system.

2. The RuBee base stations under test had the capability to
operate from power level 1 to power level 7. The highest power
level was evaluated first, and then the power was decreased
until a power level was identified to achieve the goal of having
a zero safe separation distance from HERO UNSAFE/UNRELIABLE
ORDNANCE. Therefore, only power levels 7, 6, and 5 were
evaluated. The evaluation was conducted in two phases. Phase 1
testing was conducted using an electrically initiated device
(EID) that was instrumented, calibrated, and installed on loop
antennas. During calibration of the MK 71 MOD 0 EID, a minimum
detectable current (MDC) of 3.8 mA [4% of the maximum no-fire
current (MNFC)] was measured. Phase 2 testing was to determine
if multiple RuBee systems at different locations and
orientations produce aggregate effects with multiple
transmitting antennas within confined electrically reflective
spaces.

3. During Phase 1 testing using the MK 71 MOD 0 EID with an
MNFC of 94 mA at power level 5, a radio-frequency (RF)-induced
current response of 11 mA (11.7% of the MNFC) was measured on
the bridgewire at a distance of zero inches/feet between the
transmitting Ranger antenna and the instrumented loop antenna.
Since the MK 71 MOD 0 is not the most sensitive EID from a HERO
standpoint, measured induced current responses were scaled based
on the MNFC of the most sensitive EID (85 mA MNFC). Scaling the
11 mA induced current response to an 85 mA device results in an
RF-induced current level of 12.9% of the MNFC. The 12.9%
induced current level did not exceed the 15% MNFC pass/fail
criterion for safety in the 85 mA EID. At zero inches/feet, the
pRap reader had no RF-induced current responses (below MDC) on
the MK 71 MOD 0 EID at power level 7. Scaling the 3.8 mA
(MDC = 4%) current level to the 85 mA MNFC results in a current
level of 4.5% of the MNFC. The 4.5% current level did not
exceed the 15% MNFC pass/fail criterion for safety in the 85 mA
EID. The 1T tag is a passive radio-frequency identification tag
that uses backscatter technology. The measured RF energy from

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the 1T tag was two orders of magnitude less (20 dB) than the RF energy transmitted by the pRap reader. In Phase 2 testing, the resultant electric and magnetic fields of one versus two transmitting antennas at power level 5 located 8 feet apart and in different orientations did not result in an increase in electric and magnetic field measurements.

4. Based on the HERO safety evaluation test results, NSWCDD (Q52) concludes that at power level 5, the RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] with the Ranger antenna (RP-A351) can operate safely at a zero safe separation distance to HERO UNSAFE/UNRELIABLE ORDNANCE, but the antenna terminals must not come in direct contact with ordnance, as prescribed by the guidance in reference (c). In addition, the pRap reader (PRP-100) has a zero safe separation distance from HERO UNSAFE/UNRELIABLE ORDNANCE, as prescribed by the guidance in reference (c), and the 1T tags (TID-100-W-1T-S) have no HERO restrictions. Therefore, NSWCDD (Q52) recommends that the RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] be designed to have maximum power output at power level 5. In the case of operational use of multiple RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] with as many as two Ranger antennas (RP-A351), it is recommended that a minimum of 8 feet separation distance be maintained between two transmitting Ranger antennas in free space and in confined electrically reflective spaces. NSWCDD (Q52) will need to review any modifications to the evaluated equipment to ensure that there are no changes that might affect the conclusions in this test report.

5. For Navy applications, the Naval Ordnance Safety and Security Activity will make the final recommendation regarding HERO certification once it has received a request from the product manager, acquisition manager, or installation activity delineating the intended deployment, along with a risk mitigation plan. This letter provides the necessary HERO guidance to develop a risk mitigation plan. That plan is required in order to achieve formal HERO certification. Certification is mandated by reference (d) to ensure ordnance safety prior to introduction of RF emitters into the fleet.

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6. Enclosure (1), the HERO safety evaluation test report, provides the test configuration, test methodology, discussion of radiated emissions characterization, emission measurements, and conclusions and recommendations based upon those results. The HERO safety evaluation test was conducted in accordance with the conditions and procedures outlined in enclosure (2), the HERO safety evaluation test plan.

7. If there are any questions or comments, please contact Michael Slocum (Q52) at commercial (540) 653-2212 or DSN 249-2212, or via electronic mail at michael.slocum@navy.mil.



RICHARD F. MAGROGAN
By direction

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HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE SAFETY EVALUATION TEST REPORT FOR NEAR-TOUCHING USE OF THE RUBEE (IEEE 1902.1) BASE STATION WITH RANGER ANTENNA, 1T TAGS, AND pRAP READER IN PROXIMITY TO HERO UNSAFE/ UNRELIABLE ORDNANCE

MAY 2012



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RUBEE (IEEE 1902.1) BASE STATION WITH RANGER ANTENNA,
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May 2012

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EXECUTIVE SUMMARY

As requested by Visible Assets, Inc., a Hazards of Electromagnetic Radiation to Ordnance (HERO) safety evaluation test of the RuBee (IEEE 1902.1) base station with Ranger antenna, 1T tags, and pRap reader was conducted in November 2011 at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) (Q52), Dahlgren, Virginia.

The purpose of the HERO safety evaluation test was to determine if a zero safe separation distance from HERO UNSAFE/UNRELIABLE ORDNANCE as defined in NAVSEA OP 3565/NAVAIR 16-1-529, Volume 2, Eighteenth Revision of 1 April 2011 can be achieved during operational use of the RuBee system.

The RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] under test have the capability to operate from power level 1 to power level 7. The highest power level was evaluated first, and then the power was decreased until a power level was identified to achieve the goal of having a zero safe separation distance from HERO UNSAFE/UNRELIABLE ORDNANCE. Therefore, only power levels 7, 6, and 5 were evaluated. The evaluation was conducted in two phases. Phase 1 testing was conducted using an electrically initiated device (EID) that was instrumented, calibrated, and installed on loop antennas. During calibration of the MK 71 MOD 0 EID, a minimum detectable current (MDC) of 3.8 mA [4% of the maximum no-fire current (MNFC)] was measured. Phase 2 testing was to determine if multiple RuBee systems at different locations and orientations produce aggregate effects with multiple transmitting antennas within confined electrically reflective spaces.

During Phase 1 testing using the MK 71 MOD 0 EID with an MNFC of 94 mA at power level 5, an RF-induced current response of 11 mA (11.7% of the MNFC) was measured on the bridgewire at a distance of zero inches/feet between the transmitting Ranger antenna and the instrumented loop antenna. Since the MK 71 MOD 0 is not the most sensitive EID from a HERO standpoint, measured induced current responses were scaled based on the MNFC of the most sensitive EID (85 mA MNFC). Scaling the 11 mA induced current response to an 85 mA device results in an RF-induced current level of 12.9% of the MNFC. The 12.9% induced current level did not exceed the 15% MNFC pass/fail criterion for safety in the 85 mA EID. Therefore, the RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] set to power level 5 with the Ranger antenna (RP-A351) have a zero safe separation distance from HERO UNSAFE/UNRELIABLE ORDNANCE, but the antenna terminals must not come in direct contact with ordnance. NSWCDD (Q52) recommends that the RuBee base stations be designed to have maximum power output at power level 5.

The pRap reader (PRP-100) had no RF-induced current responses (below MDC) at zero inches/feet on the MK 71 MOD 0 EID at power level 7. Scaling the 3.8 mA (MDC = 4%) current level to the 85 mA MNFC results in a current level of 4.5% of the MNFC. The 4.5% current level did not exceed the 15% MNFC pass/fail criterion for safety in the 85 mA EID. Therefore, the pRap reader has a zero safe separation distance from HERO UNSAFE/UNRELIABLE ORDNANCE.

The 1T tag (TID-100-W-1T-S) is a passive radio-frequency identification tag that uses backscatter technology. The measured RF energy from the 1T tag was approximately two orders

of magnitude less (20 dB) than the RF energy transmitted by the pRap reader. Therefore, there is no HERO restriction for 1T tag.

In Phase 2 testing, the resultant electric and magnetic fields of one versus two transmitting antennas at power level 5 located 8 feet apart and in different orientations did not result in an increase in electric and magnetic field measurements. Therefore, at power level 5 with as many as two transmitting Ranger antennas, it is recommended that a minimum of 8 feet separation distance be maintained between two transmitting Ranger antennas in free space and in confined electrically reflective spaces. NSWCCD (Q52) will need to review any modifications to the evaluated equipment to ensure that there are no changes that might affect the conclusions in this test report.

For Navy applications, the Naval Ordnance Safety and Security Activity will make the final recommendation regarding HERO certification once it has received a request from the product manager, acquisition manager, or installation activity delineating the intended deployment, along with a risk mitigation plan. The cover letter to this document provides the necessary HERO guidance to develop a risk mitigation plan. That plan is required in order to achieve formal HERO certification. Certification is mandated by NAVSEAINST 8020.7D of 1 August 2008 to ensure ordnance safety prior to introduction of RF emitters into the fleet.

Please address questions or comments concerning this report to:

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GLOSSARY

AIT	Automatic Identification Technology
Att	Attenuation
ClrW	Clear write
dB	Decibel
dBm	Decibels above (or below) 1 milliwatt
DoD	Department of Defense
DSN	Defense Switched Network
E3	Electromagnetic Environmental Effects
EID	Electrically Initiated Device
EMR	Electromagnetic Radiation
ft	Feet
HERO	Hazards of Electromagnetic Radiation to Ordnance
IEEE	Institute of Electrical and Electronics Engineers
kHz	Kilohertz
mA	Milliampere
MDC	Minimum Detectable Current
MK	Mark (weapons)
MNFC	Maximum No-Fire Current
MOD	Model/Modification
ms	Millisecond
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAVSEAINST	NAVSEA Instruction
NSWC	Naval Surface Warfare Center
NSWCDD	Naval Surface Warfare Center, Dahlgren Division
nW	Nanowatt
OATS	Open-Air Test Site
OP	Ordnance Publication
P/N	Part Number
RBW	Resolution Bandwidth
Ref	Reference level
RF	Radio Frequency
RMS	Root Mean Square
S/N	Serial Number
SGL	Single sweep
SWT	Sweep Time
VBW	Video Bandwidth
μTesla	Microtesla

1.0 INTRODUCTION

Electromagnetic radiation (EMR) produced by automatic identification technology (AIT) equipment can inadvertently actuate or dud electrically initiated devices (EIDs) contained in ordnance. The EMR can be coupled electrically to EIDs directly from the radiated field, such as through enclosure apertures. EMR also can be conducted to EIDs through ordnance systems' power, signal/control, and EID firing lines. Inadvertent actuation or dudding of EIDs can cause injury to personnel, destruction of equipment, or degradation of system performance. The inadvertent actuation or dudding of electrically initiated ordnance by EMR is known as Hazards of Electromagnetic Radiation to Ordnance (HERO).

It is essential that AIT equipment and other wireless applications equipment be tested to ensure control over the potential for HERO.

2.0 BACKGROUND

Visible Assets, Inc., is the provider of the RuBee system, the equipment under test. The RuBee system is comprised of a transmitter and transceiver. The operating frequency of the transmitter is approximately 131 kHz.

The RuBee system is a packet-based, wireless protocol used for high-security, wireless visibility networks for mission-critical assets. The system is an Institute of Electrical and Electronics Engineers (IEEE)-issued standard (IEEE 1902.1) designed for asset visibility applications that require high security, high human safety, and low electromagnetic interference in harsh environments. The system produces very low levels of radio-frequency (RF) power, and nearly all of the energy from a RuBee antenna is magnetic. For this test, only power levels 7, 6, and 5 were used to measure and collect data.

The items listed in Table 1 (hereinafter referred to collectively as the "Visible Assets equipment") are intended for use in the tracking and inventory of ammunition, ordnance containers, or pallets of electrically initiated ordnance utilizing portable battery-powered barcode scanning devices. The Visible Assets equipment is intended for use in ordnance storage, assembly, and production areas.

As requested by Visible Assets, Inc., a HERO safety evaluation test of the Visible Assets equipment was conducted in November 2011 at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD). NSWCDD (Q52) personnel conducted the test.

3.0 PURPOSE

The purpose of the HERO safety evaluation test was to determine if a zero safe separation distance from HERO UNSAFE/UNRELIABLE ORDNANCE as defined in Reference 1 can be achieved during operational use of the RuBee system.

TABLE 1. VISIBLE ASSETS EQUIPMENT

ITEM	QUANTITY	PART/SERIAL NUMBER
RuBee Base Station	2	Sidewinder (SW-121) P/N SW-122-100 S/N SWIS12100170
		Blaster (Base-110) P/N 102000-05 S/N NB-02071180
RuBee Ranger Antenna	2	RP-A351
RuBee pRap Reader, no barcode	1	PRP-100
RuBee 1T Tag	3	TID-100-W-1T-S
Finder Software	1	v 10.16

4.0 SCOPE

The HERO safety evaluation test was designed to simulate or duplicate conditions under which the Visible Assets equipment can be used safely with electrically initiated ordnance. The test was based on the configuration/mode yielding stepped-level radiated emissions that might be used during in-service operation. The Visible Assets equipment was exercised in all modes of operation and variations in configuration to the extent possible to determine the configuration/mode resulting in the highest level of radiated emissions. Figure 1 shows the test setup in the reverberation chamber to measure the worst-case electromagnetic environment produced by this system.



FIGURE 1. TEST SETUP IN THE REVERBERATION CHAMBER

5.0 TEST RESULTS DISCUSSION

The HERO safety evaluation test for near-touching use of the Visible Assets equipment was conducted in two phases. The first phase of the test was an analytical investigation for relaxing the safe separation distance to zero based on the near-field relationships. The second phase of the test was to determine if multiple RuBee system transmitting antennas produce aggregate

magnetic field effects. Preliminary magnetic field measurements with the Narda (ELT-400) probe [validated with the Prodyne (B-20B) sensor] using the open-air test site (OATS) and reverberation chamber produced similar results. (See Figure 2.) Therefore, testing was conducted only in the reverberation chamber for Phases 1 and 2.

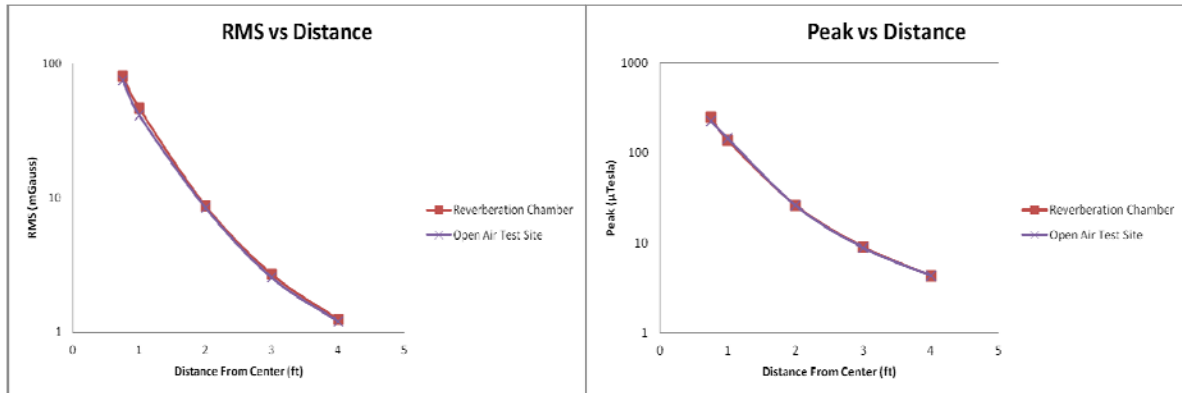


FIGURE 2. MEASUREMENTS AT OATS AND IN THE REVERBERATION CHAMBER USING THE MAGNETIC FIELD PROBE

In Phase 1 testing, according to preliminary analysis conducted using magnetic field measurements and limits generated at NSWCCD (Q52), the calculated safe separation distance for the Ranger antenna with the RuBee base station was approximately 6.7 feet. As a result of a request by Visible Assets to relax the safe separation distance restriction of the RuBee system components, a test was conducted using a sensitive EID (MK 71 MOD 0) with a maximum no-fire current (MNFC) of 94 mA (14.1 mA is 15 percent of the MNFC, safety margin). The EID was instrumented, calibrated, and installed on various loop antennas. (See Appendix B of Reference 2.) The results for the evaluated power levels of the RuBee base station are provided in Table 2. Since the MK 71 MOD 0 is not the most sensitive EID from a HERO standpoint, measured current responses were scaled based on the MNFC of the most sensitive EID [85 mA (12.8 mA is 15 percent of the MNFC, safety margin)]. Table 3 provides the scaled data. To achieve the highest level of radiated emission, the Blaster (Base-110) was used as the generating source for the EID installed loop antennas. The Blaster (Base-110) was used because it produced higher-level magnetic field measurements than the Sidewinder (SW-121).

TABLE 2. WORST-CASE EID CURRENT RESPONSES AND SAFE SEPARATION DISTANCES FROM THE RANGER ANTENNA, WITH MNFC OF 94 mA

RUBEE BASE STATION POWER LEVEL SETTING	CURRENT/PERCENT OF MNFC	SAFE SEPARATION DISTANCE (inches/feet)
7	10 mA/10.6%	30/2.5
6	7 mA/7.5%	24/2
5	11 mA/11.7%	0

TABLE 3. SCALED WORST-CASE EID CURRENT RESPONSES AND SAFE SEPARATION DISTANCES FROM THE RANGER ANTENNA, WITH MNFC OF 85 mA

RUBEE BASE STATION POWER LEVEL SETTING	CURRENT/PERCENT OF MNFC	SAFE SEPARATION DISTANCE (inches/feet)
7	10 mA/11.8%	30/2.5
6	7 mA/8.2%	24/2
5	11 mA/12.9%	0/0

The safe separation distances (identified in Table 2) from the Ranger antenna will remain the same based on the scaled 12.8 mA safety margin (15 percent of the MNFC) safe separation distances shown in Table 3. At power level 5, scaling the 11 mA induced current response results in an RF-induced current level equivalent to 12.9% of the MNFC. The 12.9% induced current level did not exceed 15% MNFC pass/fail criterion for safety in the 85 mA EID. Results of the test using the MK 71 MOD 0 EID at power level 5 indicated that the RuBee base station with the Ranger antenna requires a zero safe separation distance from HERO UNSAFE/ UNRELIABLE ORDNANCE, but the antenna terminals must not come in direct contact with ordnance.

At zero inches/feet, the pRap reader had no RF-induced current responses (below MDC) on the MK 71 MOD 0 EID at power levels 7, 6, and 5, as shown in Table 4. Scaling the 3.8 mA (MDC = 4%) current level to the 85 mA MNFC results in a current level of 4.5% of the MNFC, as shown in Table 5. The 4.5% current level did not exceed the 15% MNFC pass/fail criterion for safety in the 85 mA EID. Therefore, the pRap reader has a zero safe separation distance.

TABLE 4. WORST-CASE EID CURRENT RESPONSES AND SAFE SEPARATION DISTANCES FROM THE pRAP READER, WITH MNFC OF 94 mA

RUBEE BASE STATION POWER LEVEL SETTING	CURRENT/PERCENT OF MNFC	pRAP READER (NO BARCODE) (inches/feet)
7	<3.8 mA/<4%*	0/0
6	<3.8 mA/<4%*	0/0
5	<3.8 mA/<4%*	0/0

*MDC

TABLE 5. SCALED WORST-CASE EID CURRENT RESPONSES AND SAFE SEPARATION DISTANCES FROM THE pRAP READER, WITH MNFC OF 85 mA

RUBEE BASE STATION POWER LEVEL SETTING	CURRENT/PERCENT OF MNFC	pRAP READER (NO BARCODE) (inches/feet)
7	<3.8 mA/<4.5%	0/0
6	<3.8 mA/<4.5%	0/0
5	<3.8 mA/<4.5%	0/0

The 1T tag is a passive radio-frequency identification tag that uses backscatter technology. The measured RF energy from the 1T tag was approximately two orders of magnitude less (20 dB) than the RF energy transmitted by the pRap reader, as identified in Figure 3. Therefore, there is no HERO restriction for the 1T tag.

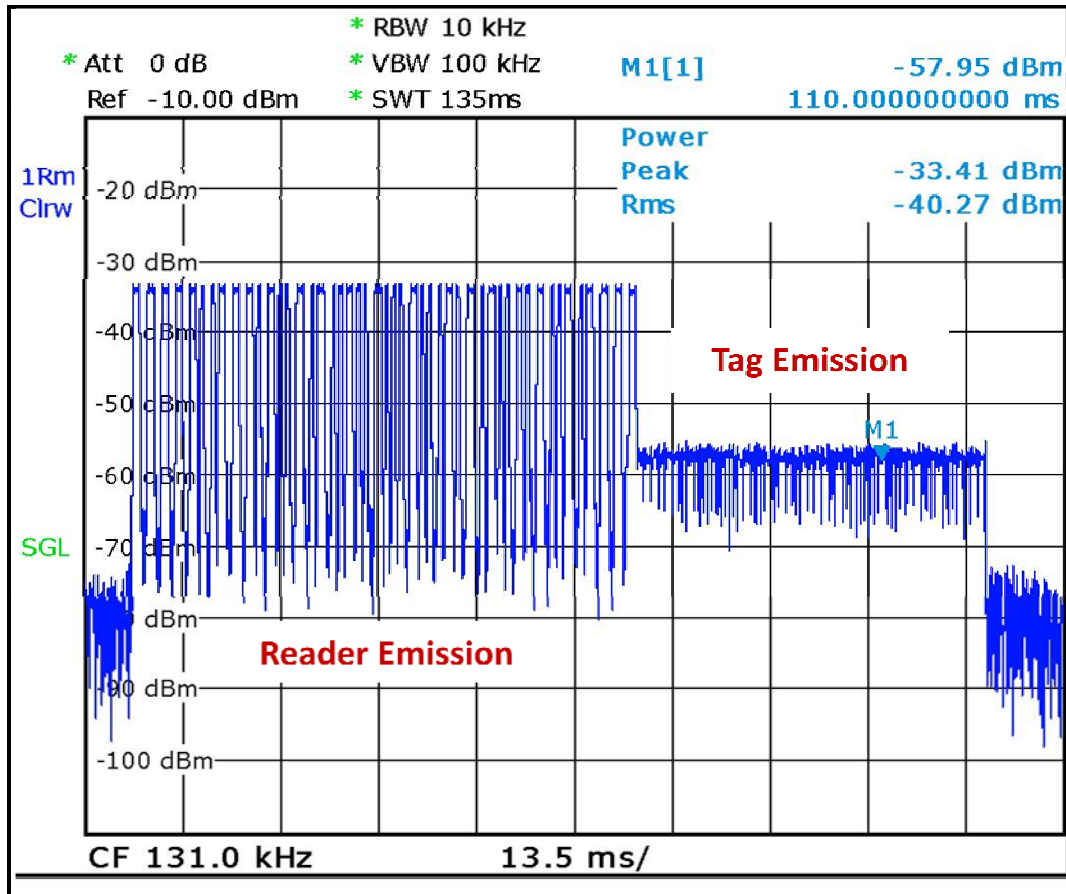


FIGURE 3. MEASURED pRAP READER AND 1T TAG EMISSIONS

Phase 2 testing was comprised of two RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] with Ranger antennas (RP-A351) operated at different orientations and distances from each other, as identified in Reference 2. These orientations and distances cover the different aspect angles in which two Ranger antennas will be operated in close proximity to each other. Only two Ranger antennas and RuBee base stations were provided for this phase of testing. Measurements were recorded from one transmitting antenna, then from two transmitting antennas. The second transmitting antenna was placed in different orientations with respect to the first antenna. Initially, measurements were recorded with the second transmitting antenna in eight different orientations. Comparison of measurements at opposite orientations showed similar results; therefore, measurements were reduced to three different orientations. Comparing the resultant electric and magnetic fields of one versus two transmitting antennas at power level 5 at 8 feet apart and different orientations did not result in an increase in electric and

magnetic field measurements. Therefore, at power level 5 with as many as two transmitting antennas, an 8-foot separation distance must be maintained between two transmitting Ranger antennas in free space and confined electrically reflective spaces.

6.0 CONCLUSIONS

Based on the results of this HERO safety evaluation test, at power level 5, the RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] with the Ranger antenna (RP-A351) can operate safely at a zero safe separation distance to HERO UNSAFE/UNRELIABLE ORDNANCE, but the antenna terminals must not come in direct contact with ordnance, as prescribed by the guidance in Reference 1. In addition, the pRap reader (PRP-100) has a zero safe separation distance from HERO UNSAFE/UNRELIABLE ORDNANCE, as prescribed by the guidance in Reference 1. The 1T tags (TID-100-W-1T-S) have no HERO restrictions.

7.0 RECOMMENDATIONS

NSWCDD (Q52) recommends that the RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] be designed to have maximum power output at power level 5. At the power level 5 setting, the RuBee system antenna terminals must not come in direct contact with HERO UNSAFE/UNRELIABLE ordnance. In the case of operational use of multiple RuBee base stations [Blaster (Base-110) and Sidewinder (SW-121)] with as many as two Ranger antennas (RP-A351), it is recommended that a minimum of 8 feet separation distance be maintained between two transmitting Ranger antennas in free space and in confined electrically reflective spaces. NSWCDD (Q52) will need to review any modifications to the evaluated equipment to ensure that there are no changes that might affect the conclusions in this test report. This approach will ensure that the various electronic equipment used aboard ship will be able to function with limited risk of performance degradation and reduce the threat to HERO UNSAFE/UNRELIABLE ORDNANCE.

8.0 REFERENCES

1. Electromagnetic Radiation Hazards (Hazards to Ordnance), NAVSEA OP 3565/NAVAIR 16-1-529, Volume 2, Eighteenth Revision, 1 Apr 2011.
2. Hazards of Electromagnetic Radiation to Ordnance Safety Evaluation Test Plan for Near-Touching Use of the RuBee (IEEE 1902.1) Base Station with Ranger Antenna, 1T Tags, and pRAP Reader in Proximity to HERO UNSAFE/UNRELIABLE ORDNANCE, Nov 2011, NSWCDD, Dahlgren, VA.

HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE SAFETY EVALUATION TEST PLAN FOR NEAR-TOUCHING USE OF THE RUBEE (IEEE 1902.1) BASE STATION WITH RANGER ANTENNA, 1T TAGS, AND pRAP READER IN PROXIMITY TO HERO UNSAFE/UNRELIABLE ORDNANCE

NOVEMBER 2011



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**NAVAL SURFACE WARFARE CENTER DAHLGREN
E3 ASSESSMENT & EVALUATION (Q52)
DAHLGREN, VA 22448-5153**

Enclosure (2)

HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE SAFETY
EVALUATION TEST PLAN FOR NEAR-TOUCHING USE OF THE RUBEE
(IEEE 1902.1) BASE STATION WITH RANGER ANTENNA, 1T TAGS,
AND pRAP READER IN PROXIMITY TO HERO
UNSAFE/UNRELIABLE ORDNANCE

November 2011

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GLOSSARY

AIT	Automatic Identification Technology
cm	Centimeters
DoD	Department of Defense
DoDIC	Department of Defense Identification Code
DSN	Defense Switched Network
E3	Electromagnetic Environmental Effects
EID	Electrically Initiated Device
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
EMR	Electromagnetic Radiation
EUT	Equipment Under Test
HERO	Hazards of Electromagnetic Radiation to Ordnance
Hz	Hertz
IEEE	Institute of Electrical and Electronics Engineers
in	Inches
IP	Internet Protocol
kHz	Kilohertz
LED	Light-Emitting Diode
m	Meters
mA	Milliamperes
MHE	Material Handling Equipment
MK	Mark (weapons)
MNFC	Maximum No-Fire Current
MOD	Model/Modification
NALC	Navy Ammunition Logistic Code
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NSWC	Naval Surface Warfare Center
NSWCDD	Naval Surface Warfare Center, Dahlgren Division
NSWCDL	Naval Surface Warfare Center, Dahlgren Laboratory
nW	Nanowatts
OATS	Open-Area Test Site
OP	Ordnance Publication
OPS	Operational Procedures Supplement
P/N	Part Number
POC	Point of Contact
PPE	Personal Protective Equipment
RF	Radio Frequency
RHC	Risk Hazard Checklist
S/N	Serial Number
SOP	Standard Operating Procedure
UAV	Unmanned Aerial Vehicle
USB	Universal Serial Bus
VAC	Volts Alternating Current
WHE	Weapons Handling Equipment

1.0 INTRODUCTION

Electromagnetic radiation (EMR) produced by automatic identification technology (AIT) equipment can inadvertently actuate or dud electrically initiated devices (EIDs) contained in ordnance. The EMR can be coupled electrically to EIDs directly from the radiated field, such as through enclosure apertures. EMR also can be conducted to EIDs through ordnance systems' power, signal/control, and EID firing lines. Inadvertent actuation or dudding of EIDs can cause injury to personnel, destruction of equipment, or degradation of system performance. The inadvertent actuation or dudding of electrically initiated ordnance by EMR is known as Hazards of Electromagnetic Radiation to Ordnance (HERO).

It is essential that AIT equipment and other wireless applications equipment be tested to ensure control over the potential for HERO.

2.0 BACKGROUND

Visible Assets, Inc., is the provider of the RuBee System, the equipment under test (EUT). The RuBee system is comprised of a transmitter and transceiver. The operating frequency and nominal output power of the transmitter are listed as approximately 131 kHz and 40 nW, respectively.

The RuBee system is a packet-based, wireless protocol used for high security, wireless visibility networks for mission-critical assets. The system is an Institute of Electrical and Electronics Engineers (IEEE)-issued standard (IEEE 1902.1) designed for asset visibility applications that require high security, high human safety, and low electromagnetic interference in harsh environments. These systems produce very low levels of radio-frequency (RF) power, and nearly all of the energy from a RuBee antenna is magnetic.

The items listed in Table 1 (hereinafter referred to collectively as the "Visible Assets equipment") are intended for use in the tracking and inventory of ammunition, ordnance containers, or pallets of electrically initiated ordnance utilizing portable battery-powered barcode scanning devices. The Visible Assets equipment is intended for use in ordnance storage, assembly, and production areas. Therefore, EMR emitted from the Visible Assets equipment can pose a potential for HERO. The RuBee system components and setup are shown in Figure 1.

TABLE 1. VISIBLE ASSETS EQUIPMENT

ITEM	QUANTITY	PART/SERIAL NUMBER
RuBee Base Station	2	Sidewinder (SW-121) P/N SW-122-100 S/N SWIS12100170
		Blaster (Base-110) P/N 102000-05 S/N NB-02071180
RuBee Ranger Antenna	2	RP-A351
RuBee 1T Tag	3	TID-100-W-1T-S
RuBee pRap Reader, no barcode	1	PRP-100
Finder Software	1	v 10.16

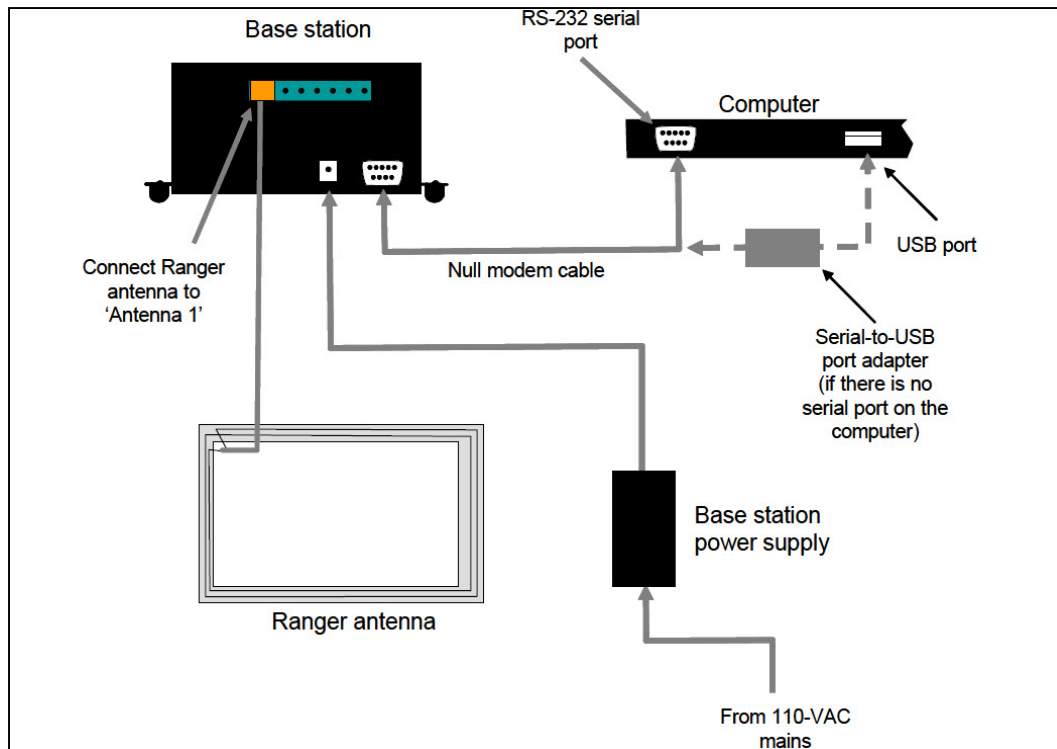


FIGURE 1. RUBEE SYSTEM COMPONENTS AND SETUP

3.0 PURPOSE

The purpose of the HERO safety evaluation test is to determine if a zero safe separation distance from HERO UNSAFE/UNRELIABLE ORDNANCE as defined in Reference 1 can be achieved during operational use of the RuBee system.

4.0 SCOPE

The conditions under which the Visible Assets equipment can be used safely with electrically initiated ordnance will be based on the configuration/mode yielding stepped-level radiated emissions that are to be used in the field. The Visible Assets equipment will be exercised in all modes of operation and variations in configuration to the extent possible to determine the configuration/mode resulting in the highest level radiated emissions. The radiated emissions will be considered from both in-band and out-of-band signals.

5.0 SYSTEM TEST CONFIGURATION

The Visible Assets equipment will be set up to operate, to the extent possible, as it would in its intended operational environment. During testing, care will be taken to ensure isolation of the measurement equipment from the test environment. All data will be corrected for losses in the measurement system equipment setup (such as cable, connectors, and connector adapter losses).

The AIT equipment will be exercised such that the EUT will transmit at transmission powers ranging from 3 to 7, and at the highest transactions per second at the maximum possible output power. Setting this operating condition may involve efforts such as configuring the test setup to reduce the signal-to-noise ratio of the equipment's communication link intentionally.

6.0 MEASUREMENT APPARATUS

OpSens: During the HERO test, fiber-optic sensors will detect ohmic heating of the bridgewires. The sensors' output will be coupled to a fiber-optic monitoring system via optical fiber. A strip-chart recorder will be used to provide a permanent, real-time record of the instrumented EID responses. All instrumentation will be provided by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) (Q52).

Prior to the test, the instrumented EIDs will be calibrated by injecting a known stimulus into the bridgewire and monitoring the output signal from the recording system. From this calibration, the EID/instrumentation sensitivity and dynamic range will be determined and recorded for future reference. Table B-1 and Figure B-5 of Appendix B provide information on the EID and illustrate the instrumentation.

Prodyne (B-20B): The sensor is a full-cylinder loop that measures the time rate-of-change of a magnetic field. It is a portable device designed for making free-field measurements. For this type of measurement, the sensor should be supported by dielectric materials and placed no closer than two sensor diameters from conducting surfaces. The sensor design consists of a conducting cylinder that contains four equally spaced longitudinal gap structures.

Narda (ELT-400): This instrument covers a wide frequency range (1 Hz to 400 kHz) and has an external isotropic magnetic field probe with a 100 cm² cross-sectional area, making it suitable for standards-compliant measurements, even in inhomogeneous fields.

7.0 HERO TEST FACILITY

The HERO test will be conducted using the NSWCDD (Q52) reverberation chamber and open-area test site (OATS) facilities located in Dahlgren, Virginia.

The reverberation chamber facility is an electromagnetically shielded enclosure where injected electromagnetic energy from an RF source establishes statistically predictable resonant electromagnetic environments (EMEs) at frequencies where the chamber dimensions are large compared to EME wavelengths. The simultaneously existing modes of electromagnetic energy are "stirred" by two orthogonal field-perturbing devices referred to as "paddle-wheel tuners." As the tuners rotate using stepper motors, the complex standing wave patterns vary as a function of paddle-wheel tuner position, thereby resulting in the exposure to randomized fields from all directions and field polarizations.

The OATS facility is an electrically conductive surface that is highly reflective. This characteristic is used to simulate the deck of a ship.

8.0 HERO EVALUATION REQUIREMENTS

The EUT will be evaluated for use under the conditions that represent service use. The Visible Assets equipment will be used at near-touching distances to electrically initiated ordnance. Therefore, this test will determine the minimum distance from a worst-case EID model that the Visible Assets equipment can be used in the field, based on the maximum B-field that can be radiated by the RuBee system with the Ranger antenna, 1T tags, and pRap reader without presenting a potential for HERO.

In addition, multiple RuBee systems will be evaluated for free-space and below-deck (enclosed, reflective spaces) use of intentional transmitters on ships. This test will help measure the resultant magnetic fields generated by the system(s) in open and reflective spaces. These resultant fields will be used to determine the aggregate effects, if any, created by multiple emitters as pertain to a threat to HERO UNSAFE/UNRELIABLE ORDNANCE.

9.0 HERO EVALUATION PROCESS

The HERO test for near-touching use of the Visible Assets equipment will be conducted in two phases. The test procedures for these two phases that represent the operation of this system are outlined in Appendix A.

The first phase of the test will be an analytical investigation for relaxing the safe separation distance to zero based on the near-field relationships. This testing will be conducted using EIDs that will be instrumented, calibrated, and installed on various loops (Appendix B) using the OATS and reverberation facilities.

The second phase of the test will be to determine if multiple RuBee system transmitting antennas produce aggregate magnetic field effects. Testing will be performed on multiple RuBee systems with the Ranger antennas spaced a minimum of 8 feet apart to measure the resultant magnetic fields in free space and in enclosed, reflective spaces. This approach will ensure that the various electronic equipment used aboard ship will be able to function with limited risk of performance degradation, and to determine if the resultant fields pose a threat to HERO UNSAFE/UNRELIABLE ORDNANCE.

10.0 TEST MANAGEMENT REQUIREMENTS

The test director is responsible for planning, conducting, and reporting the HERO safety evaluation test. The planning phase consists of all pretest coordination efforts necessary to obtain the hardware for testing, test facility preparation, and test plan preparation. Conducting the test includes setting up the test configurations, operating the measurement equipment, and recording the data. The reporting phase of this test event includes the preparation and delivery of a final report promulgated by an official letter. The test report provides the results, conclusions, and recommendations from the HERO safety evaluation test.

10.1 TEST SUPPORT PERSONNEL

The personnel listed in Table 2 will support this HERO test.

TABLE 2. TEST SUPPORT PERSONNEL

ORGANIZATION	PERSONNEL	FUNCTION
NSWCDD (Q52)	Jeeno Chandy	HERO Test Director
URS	George Evinger	HERO Instrumentation Technician
NSWCDD (G31)	Casey Leicht	Engineer Aide

10.2 GOVERNMENT/CONTRACTOR SUPPORT

Government/contractor support may be necessary during the test procedures. Contractor-provided information will be necessary to attain technical familiarity with the system. This information includes a description of operation of the Visible Assets equipment and the equipment's operating frequency, output power, and antenna gain.

10.3 TEST SUPPORT EQUIPMENT

NSWCDD will provide the measurement/recording equipment necessary for the performance of this test. NSWCDD also will provide the testing facility and any other ancillary equipment necessary for configuring the test setup. The test sponsor will provide the Visible Assets equipment to serve as the EUT.

10.4 HARDWARE ASSETS

The following hardware/documentation will be required for the performance of this test:

- a. Blaster (RuBee base station),
- b. Ranger antenna,
- c. RuBee tags,
- d. RuBee pRap reader,
- e. Finder software,
- f. Narda ELT-400 (magnetic field probe),
- g. Prodyne B-dot sensor (B-20B),
- h. Rohde & Schwarz FSL18 spectrum analyzer,
- i. Four instrumented MK 71s with OpSens fiber-optic cable (Appendix B),
- j. Dash 18 software (EID response),
- k. ProSens signal conditioner, and
- l. Receiving loop antennas (Appendix B).

10.4.1 Hardware Delivery

All hardware and components should be delivered to:

(Outside label)

Commander

Naval Surface Warfare Center Dahlgren

(Q52/Jeeno Chandy)

5493 Marple Road, Suite 156

Dahlgren, VA 22448-5153

(Inside package marking)

Hold for Q52/Jeeno Chandy

Building 1530, Room 202

Phone: (540) 653-6967

Jeeno Chandy shall be notified by phone at commercial (540) 653-6967 or DSN 249-6967 when hardware is shipped.

10.4.2 Hardware Disposition

Upon completion of the test, system hardware will be returned to its designated shipping point or retained for future testing, as directed by the cognizant project authority.

10.5 TEST SCHEDULE

The test is scheduled for November 2011 at NSWCDD, Dahlgren, Virginia.

10.6 TEST REPORT

A final test report detailing test results, conclusions, and recommendations will be issued by NSWCDD within 45 days of test data analysis.

11.0 SAFETY PRECAUTIONS AND STANDARD OPERATING PROCEDURES

The OATS and reverberation chamber test facility general safety precautions and ordnance systems testing standard operating procedures (SOPs) are provided in References 2 and 3, respectively. All test personnel will be fully familiar with the safety precautions and SOPs contained in these documents and will be required to perform such procedures when necessary. Prior to the start of the test, the test director will conduct a detailed safety briefing of all assigned personnel. This will include, but will not be limited to, safety precautions, hazards of high-level EMEs, and explosive/electrical safety. Refresher safety briefings will be presented by the test director on a daily basis prior to test commencement.

The Risk Hazard Checklist (RHC) provided in Appendix C must be reviewed and signed by the Q Department Safety Officer prior to testing. When the RHC indicates that the device under

test introduces hazards not covered by the applicable SOP(s), the additional hazards shall be addressed via a test-unique Operational Procedures Supplement (OPS) that shall be approved/signed separately. An OPS is not required for this test.

12.0 REFERENCES

1. Electromagnetic Radiation Hazards (Hazards to Ordnance), NAVSEA OP 3565/NAVAIR 16-1-529, Volume 2, Eighteenth Revision, 1 Apr 2011.
2. NSWCDD SOP No. XSU-OS-007-08, Standard Operating Procedure for Q50 Electromagnetic Environmental Effects Research, Development, Test & Evaluation Activities Using the NSWCDD/Q50 Ground-Plane Test Facilities, Dahlgren, VA, 6 Apr 2010.
3. NSWCDD SOP No. XSU-IS-001-07, Standard Operating Procedure (SOP) for Radio-Frequency Testing in a Reverberation Chamber, Dahlgren, VA, 26 Mar 2007.

APPENDIX A
TEST PROCEDURES

APPENDIX A TEST PROCEDURES

The test procedures described herein may be modified at the discretion of the test director to identify susceptibility problems. The cognizant project office will be notified of such changes.

Test I – Safe Separation Distance Based on Near-Field Relationships

Initial Conditions:

- a. The Ranger antenna will be placed upright/flat on a dielectric block on the open-area test site (OATS) or in the reverberation chamber.
- b. The receiving loop antennas with an electrically initiated device (EID) will be positioned either coaxial or coplanar to the Ranger antenna, beginning at near touching and moving outward at increments of 0.25 foot up to 7 feet, and at 0.5-foot increments after 7 feet. This test will be repeated for each power level from 3 to 7 on the base station.

Connecting the computer to the Blaster (base station)

- c. Once the Finder software is open, select Antenna 1 and COM 1.
- d. Click Tune. Clicks should be audible, and the yellow light-emitting diode (LED) should blink on the Blaster while the system gets tuned (best-tuned antennas are sharp and dead-on in the middle).

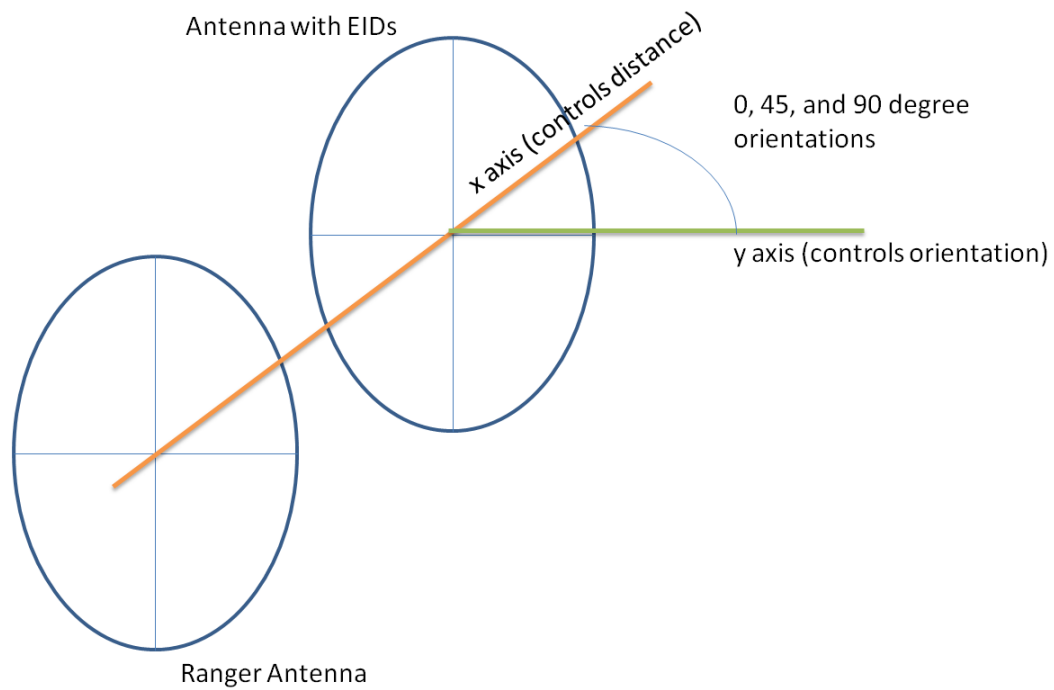
Configuring tag IP addresses

- e. Tags can be entered into the Finder software manually or through the Discover mode.
- f. Manually--Enter tag numbers (IP address) for each of the tags into the spreadsheet. All the tags that are in detection range will turn green, and the others will turn red.
- g. Discover--Click on All, New Only, and Group 1; then click Go. All the tags that are in detection range will turn green, and the others will turn red.
- h. Click Stop to end detection.

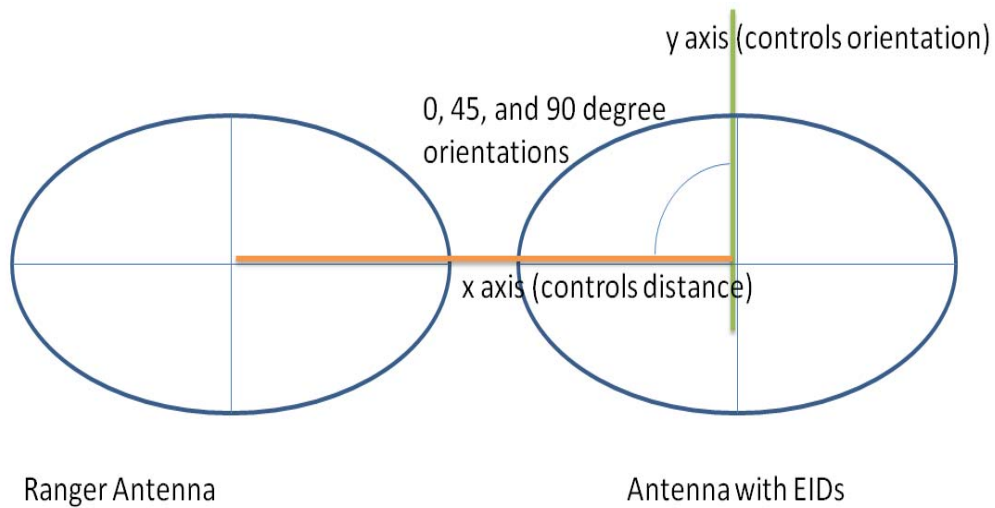
Procedures on OATS and in the Reverberation Chamber:

- 1. Set up antennas in the 0/45/90-degree orientations and at set distances apart as in Figure A-1, and set up tags in detection range.
- 2. On the Finder software spreadsheet, confirm all tag IP addresses for all tags in detection range.

3. Click Go to initiate communication, and measure the EID response, if any, generated by the Ranger antenna.
4. Click Stop to disconnect communication.



Coaxial Setup



Coplanar Setup

FIGURE A-1. ANTENNA POSITIONS

Test II – Aggregate Effects of Multiple Emitters

Initial Conditions:

- a. Multiple RuBee systems with the Ranger antennas will be placed upright on dielectric blocks spaced at a minimum of 8 feet apart in the reverberation chamber.

Connecting the computer to the Blaster (base station)

- b. Once the Finder software is open, select Antenna 1 and COM 1.
- c. Click Tune. Clicks should be audible, and the yellow LED should blink on the Blaster while the system gets tuned (best-tuned antennas are sharp and dead-on in the middle).

Configuring tag IP addresses

- d. Tags can be entered into the Finder software manually or through the Discover mode.
- e. Manually--Enter tag numbers (IP address) for each of the tags into the spreadsheet. All the tags that are in detection range will turn green, and the others will turn red.
- f. Discover--Click on All, New Only, and Group 1; then click Go. All the tags that are in detection range will turn green, and the others will turn red.
- g. Click Stop to end detection.

Procedures in the Reverberation Chamber:

1. With multiple Ranger antennas set up at a minimum of 8 feet apart and tags set up in detection range, use the B-dot sensor and spectrum analyzer to make B-field measurements.
2. On the Finder software spreadsheet, confirm all tag IP addresses for all tags in detection range.
3. Click Go to initiate communication, and measure the H fields generated by the Ranger antenna. Measurements will be taken at 50 random locations/orientations within a working volume containing the multiple Ranger antennas.
4. Position receiving loop antennas with EID at 50 random locations/orientations within a working volume containing the multiple Ranger antennas. Measure EID response at each location.
5. Use the Narda magnetic field probe to make maximum-hold B-field measurements using a random walk throughout the reverberation chamber volume. Perform 12 random walk runs.
6. Click Stop to disconnect communication.

APPENDIX B

LOOP ANTENNAS AND ELECTRICALLY INITIATED DEVICES

APPENDIX B LOOP ANTENNAS AND EIDs

The following loop antennas will be used as receiving loop antennas with electrically initiated devices (EIDs) that will be instrumented, calibrated, and installed.

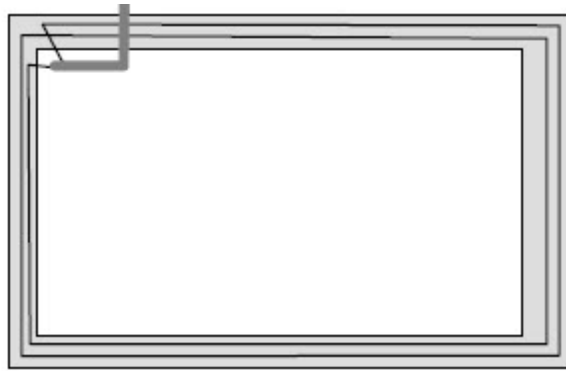


FIGURE B-1. RANGER ANTENNA LOOP (10 TURNS OF WIRE)

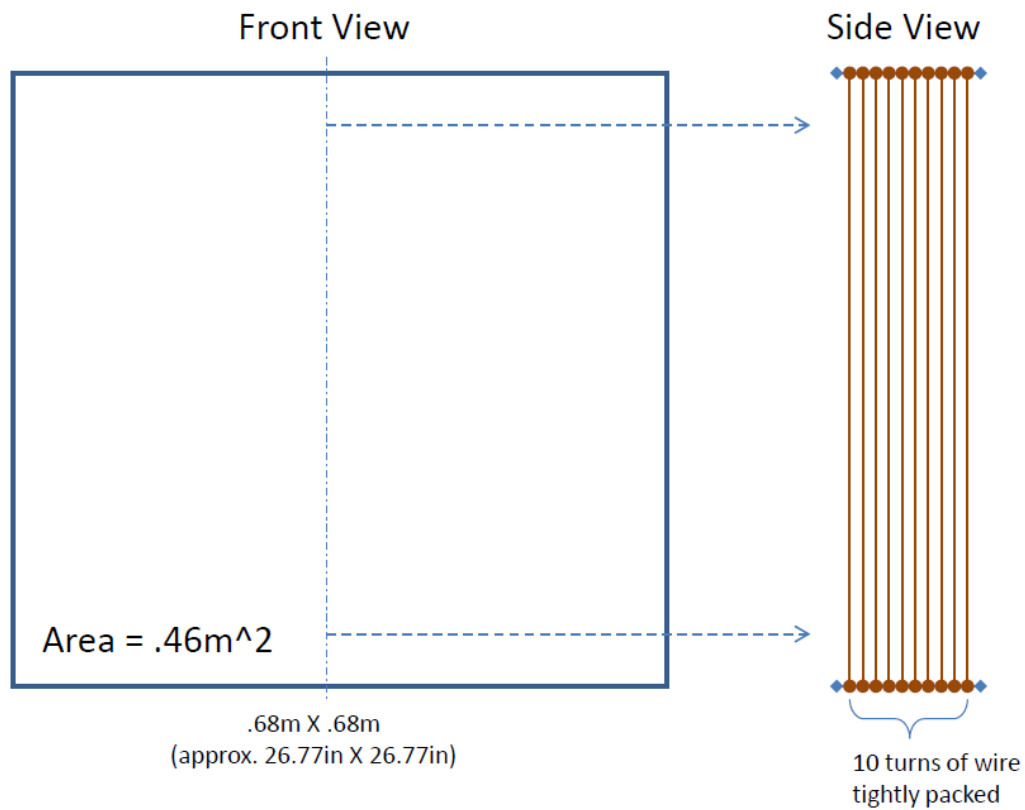


FIGURE B-2. 0.46 m^2 LOOP (10 TURNS OF WIRE)



FIGURE B-3. FIXED LOOP [5.25-INCH DIAMETER (36 TURNS OF WIRE)]



**FIGURE B-4. FIXED LOOP [28.5 X 29.75-INCH, 6.31-INCH RADIUS
(11 TURNS OF WIRE)]**

SYSTEM UNDER TEST

1. System: RuBee
2. Auxiliary Equipment: Dielectric Block
3. Platform: Receiving Loop Antennas
4. EID Firing and Electrical Characteristics: The EID reference number, component assembly, Department of Defense Identification Code (DoDIC)/Navy Ammunition Logistic Code (NALC) and/or part number, maximum no-fire current (MNFC), bridgewire resistance, and firing effect for the system under test are provided in Table B-1.

TABLE B-1. EID FIRING AND ELECTRICAL CHARACTERISTICS

EID REFERENCE NUMBER	COMPONENT ASSEMBLY	DoDIC/NALC AND/OR PART NUMBER	MNFC (mA)	BRIDGEWIRE RESISTANCE (ohms)	FIRING EFFECT: SAFETY OR RELIABILITY
1	Receiving Loop Antennas	MK 71 MOD 0	94	4.5-4.9	Safety

5. Instrumentation: The system's EIDs for the Hazards of Electromagnetic Radiation to Ordnance safety evaluation test will be instrumented as depicted in Figure B-5.

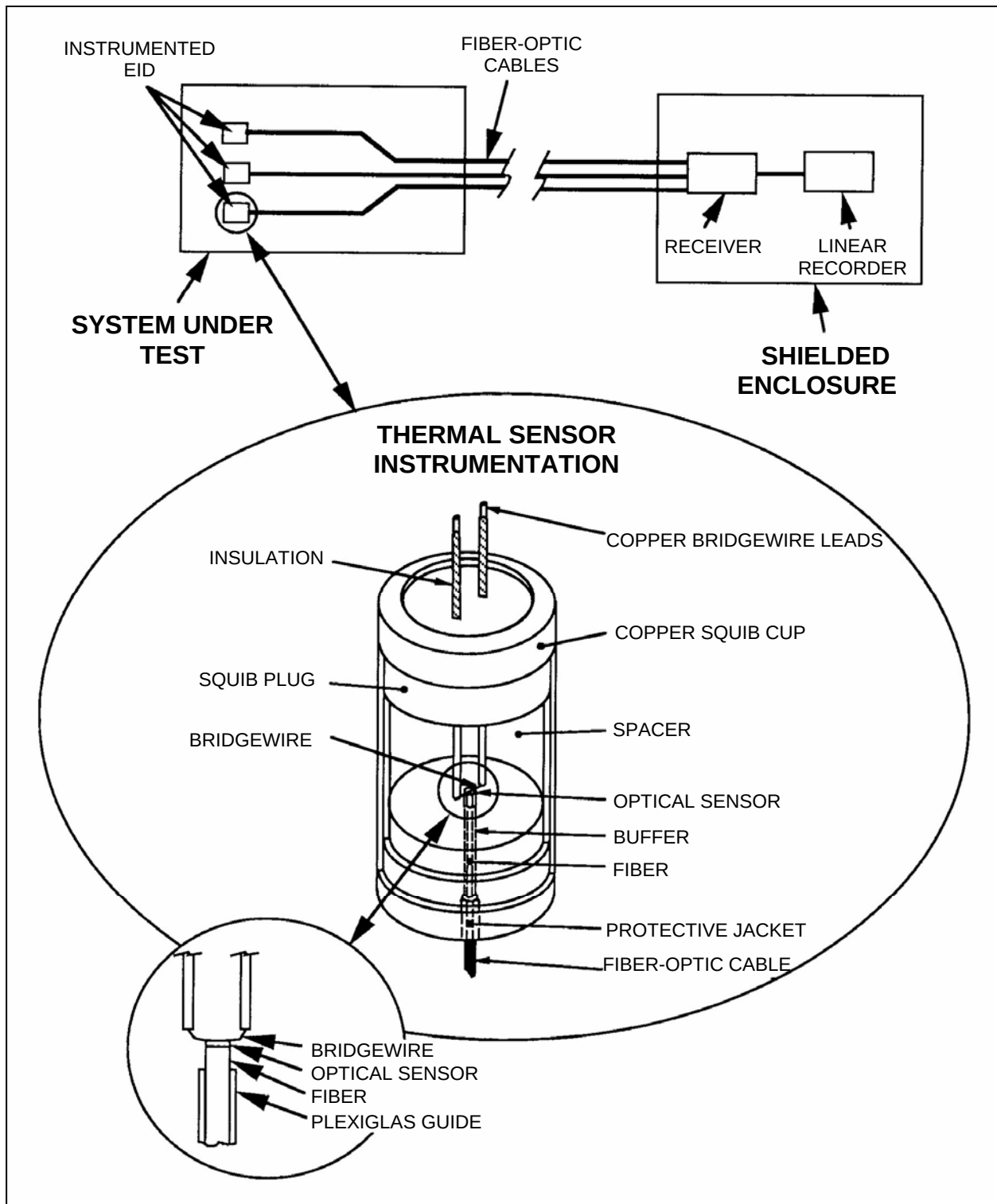


FIGURE B-5. EID INSTRUMENTATION

APPENDIX C
RISK HAZARD CHECKLIST

Risk Hazard Checklist (RHC)

RHC For: Operation Name: **HERO Safety Evaluation Test**

Equipment Under Test (EUT) Name: **RuBee Base Station with Ranger Antenna, 1T Tags, and pRap Reader**

Location of Operation: ☒ Outside or Open Air ☒ Inside ☐ Offsite

Potential Risk (check all that apply)	Potential Risk Category (If Yes is checked for a potential risk, it must be further defined in this column)	Cognizant POC(s) (If Yes or if you have questions contact the POC)	Date POC Contacted
Explosives YES NO ☐ ☒	☐ Explosive material(s) ☐ Exposure to explosive operations/facilities ☐ Other _____	John Kaelin, X3-4296 or Daniel Cordes, X3-4297	
Radiation Emissions YES NO ☒ ☐	☐ Lasers ☐ Ionizing radiation ☒ RF/EMR ☐ Other _____	Sheran Phin, X3-4298 or Courtney Baskeyfield, X3-1628 William Baker, X3-3448 (RF/EMR)	Addressed by SOP
Other Emissions YES NO ☐ ☒	☐ Acoustic (airborne) ☐ Acoustic (underwater) ☐ Intense light ☐ Noise ☐ Other _____	William Goss, X3-2335 or Richard Neil, (540)220-5354 Jackie Yang, X3-3627 (Noise)	
Air Space Utilization YES NO ☐ ☒	☐ Weapons system ☐ UAV ☐ Other _____	NSWC DL Range Control Craig Lang, X3-6390 or Mike White, X3-6388	
Environmental YES NO ☐ ☒	☐ Generate solid and/or hazardous waste ☐ Water discharge or run-off ☐ Generator use ☐ Other air/water emissions _____	Vanessa Lovejoy, X3-0933 or Gary Vick, X3-8685 Jackie Yang, X3-3627 (Generator)	
Disturbance of Natural and/or Cultural Resources YES NO ☐ ☒	☐ Impact migratory bird nesting areas ☐ Impact to bald eagles ☐ Impact wetlands ☐ Impact wooded areas ☐ Potentially result in soil erosion ☐ Ground disturbance ☐ Other _____	William Goss, X3-2335 or Richard Neil, (540)220-5354	
Toxin, Chemical, or Biological YES NO ☐ ☒	☐ Chemical(s) ☐ Biological hazards ☐ Toxins ☐ Simulates ☐ Other _____	Michael Simulcik, X3-2036	
Hazardous Material YES NO ☐ ☒	☐ The operation uses hazardous material (HM)	Susan Thomas, X3-8774	
Occupational Safety and Health YES NO ☐ ☒	☐ Working at heights greater than 4 feet ☐ Confined space ☐ Lock-Out /Tag-Out ☐ Powered tools/equipment ☐ Personal protective equipment (PPE) ☐ WHE/MHE (i.e. cranes/ forklifts/slides) ☐ Other _____	Paula Bailey, X3-1565 Jackie Yang, X3-3627 (PPE & WHE/MHE only)	

Revised: 28 June 2011

