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SUB-COMMITTEE ON SAFETY OF
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Agenda items 10 and 12

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PERFORMANCE STANDARDS FOR SHIPBORNE GALILEO RECEIVER EQUIPMENT

**Maritime navigation and radiocommunication equipment and systems – Global navigation
satellite systems**

Submitted by the United States

SUMMARY

Executive summary: The document at annex, “Results of Commercial GPS Antenna Electromagnetic Vulnerability Tests,” describes a United States investigation that has confirmed numerous reports from commercial maritime operators of GPS damage from high power shipborne radars

Action to be taken: Paragraphs 5 and 6

Related documents: Resolution A.819(19), MSC.53(66), MSC.112(73), MSC.113(73)

Background

1 The International Electrotechnical Committee (IEC) international standard 61108-1, “Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS)”, Part 1 “Global positioning system (GPS) – receiver equipment – Performance standard, methods of testing and required test results” addresses the effects of interfering signals on GPS.

2 Based on a number of anecdotal reports, GNSS receivers were believed to be failing due to radiation from nearby high power shipborne radars. Through receiver and antenna analysis and testing, a United States investigation has confirmed numerous GPS damage reports from commercial maritime operators and the results are reflected in a United States Navy report entitled “Results of Commercial GPS Antenna Electromagnetic Vulnerability Tests,” attached at annex. The investigation and test results conclude that the current maritime electromagnetic environment is significantly higher than what has been defined in IEC 61108-1, reflecting the widespread use of high power microwave radars currently in operation by the world’s naval military services.

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3 At distances of about 1,000 feet, tests showed that at least one military shipborne radar can produce a peak power density ranging from 28 to 112 KW/m². The IEC standard test limit for the same frequency band is only 7.5 KW/m².

4 The United States believes that the performance standards and test specifications for GPS, GLONASS, and other GNSS receiver equipment (e.g., Galileo) should take into account this higher electromagnetic environment.

Action requested of the Sub-Committee

5 The Sub-Committee is invited to consider the report attached at annex, “Results of Commercial GPS Antenna Electromagnetic Vulnerability Tests,” when developing performance standards for shipborne GNSS receiver equipment and decide, as appropriate.

6 The Sub-Committee is invited to approve the following draft liaison statement to IEC:

**DRAFT LIAISON STATEMENT TO IEC TECHNICAL COMMITTEE 80
WORKING GROUP 4A ON
SHIPBOARD GNSS RECEIVER EQUIPMENT**

In recognition of the increasing use of high power radars on military ships and the potential for these radars to damage GNSS receivers on commercial ships operating in the vicinity, the International Maritime Organization’s NAV Sub-Committee requests that the IEC consider this electromagnetic environment in the development or revision of relevant standards, including IEC Standard 61108, “Maritime navigation and radiocommunication equipment and standards – Global navigation satellite systems (GNSS)”.

ANNEX



SEMCIP REPORT

J54-05-016

**RESULTS OF
COMMERCIAL GLOBAL POSITIONING SYSTEM (GPS) ANTENNA
ELECTROMAGNETIC VULNERABILITY TESTS**

February 2005

By

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DISTRIBUTION STATEMENT A - Approved for public release; distribution is unlimited.

J54-05-016

This report is provided for effective identification, resolution and control of electromagnetic interference/electromagnetic compatibility (EMI/EMC) problems.

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EXECUTIVE SUMMARY

This report documents the Electromagnetic Vulnerability (EMV) of a set of commercial Global Positioning System (GPS) active antennas that were subjected to power densities that could occur when ships with high power radars radiate other ships that have GPS antennas. The GPS antennas are identified as International Maritime Organization (IMO) compliant, IMO non-compliant, or unknown.

Twenty-nine GPS antennas were tested at specific L-Band and S-Band radar frequencies on the Naval Surface Warfare Center Dahlgren Division (NSWCDD) ground plane.

GPS antenna failures in the report are defined as follows:

- **Hard non-recoverable failure** – the antenna did not recover within 5 minutes after the source was turned off, and the power to the antenna was then turned off and back on, and a failure was still indicated.
- **Hard recoverable failure** – the antenna did not recover within 5 minutes after the source was turned off, but did recover when the power to the antenna was then turned off and back on.
- **Soft failure** – the antenna recovered during the test or within 5 minutes after the source was turned off.

Two GPS antennas suffered hard non-recoverable failures. One was an IMO compliant antenna and one was not. Five antennas suffered hard recoverable failures, with one antenna suffering three hard recoverable failures in three tests. Eight antennas suffered soft failures, with some antennas suffering soft failures in more than one test.

A summary report, to be released by NSWCDD later this year will provide a complete overview of the investigation, and the testing conducted in 2004 and 2005.

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Test Results of Commercial Global Positioning System (GPS) Antenna Vulnerability Tests

1.0 PURPOSE

The perception exists that the failure of commercial Global Positioning System (GPS) active antennas on maritime vessels, whether the United States Navy (USN), U.S. Coast Guard (USCG), or commercial, is the result of radiation by off board high power shipboard radars. In May 2000, the Naval Sea Systems Command (NAVSEA) launched an investigation into GPS susceptibility after receiving USN message traffic indicating an U.S. Naval Service (USNS) ship had experienced GPS damage during a routine boarding operation training exercise with an AEGIS class destroyer. Shortly thereafter, NAVSEA was contacted by the USCG Maritime Liaison Office (MARLO) in Bahrain, who was looking for any information to explain why they were receiving so many reports from commercial vessels complaining of GPS failures while operating in the Persian Gulf. Consequently, in February 2004, the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), J54, in conjunction with the USCG conducted electromagnetic vulnerability tests on eight GPS commercial antennas on the NSWCDD Ground Plane in order to ascertain if they could survive the main beam radiant power per unit area power density (PD) caused by selected radars at 500 and 1,000 feet. Three GPS antennas failed due to the level of the PDs to which they were subjected. Consequently, a larger sample of GPS antennas was solicited from manufacturers, and 21 unique GPS antennas, with seven duplicates (an antenna with the same Model Number as one of the 21), were tested in February 2005, as described in this report. The NSWCDD effort was performed under the Shipboard Electromagnetic Compatibility Improvement Program (SEMCIP). A summary report, to be released by NSWCDD later this year will provide a complete overview of the investigation, and the testing conducted in 2004 and 2005.

2.0 DISCUSSION

To preserve manufacturer anonymity, GPS antennas tested in this report were referred to by the numbers 1 to 21, with duplicates identified by the letter "D," e.g., 12D. Most manufacturers of the GPS antennas designated their antennas as International Maritime Organization (IMO) compliant or non-compliant. In some cases, the manufacturers did not provide sufficient information to establish whether they considered their antennas IMO compliant or non-compliant. In these cases, compliance was considered unknown. In any case, reference to antennas herein as IMO-compliant, non-compliant, or unknown is based purely on information or assertions, or lack thereof, by each manufacturer, and not upon any independent evaluation by NSWCDD. The IMO is a body composed of representatives from most of the maritime nations of the world, which sets standards and certifies equipment for safety of life at sea. Designated IMO compliant, non-compliant, and unknown status GPS antennas that were tested are listed as such in Table 1. The GPS antennas were tested using the parameters in Table 2. These parameters are similar to those of Navy radars, which are believed to have caused GPS antenna failures. The parameter 29 dBm/cm² at 3250 MHz in Table 2 was performed based on Section 4.3.8 of International Standard IEC 61108-1. The parameter 37 dBm/cm² at 3250 MHz in Table 2 simulates the PD of a Navy high power radar at a distance of 1000 ft. The parameter 43 dBm/cm² in Table 2 adds a margin of 6 dB based on MIL-STD-464 (A5.1 Margins). The parameter 18 dBm/cm² at 920 MHz in Table 2 simulates the PD of another Navy high power radar at a distance of 500 ft. The periodic pulse bursts simulate a rotating or scanning radar.

Table 1. GPS Antennas Tested

No.	Antenna No.	IMO Compliant?
1	1	No
2	2	No
3	2 (Duplicate)	No
4	3	Yes
5	3 (Duplicate)	Yes
6	4	Yes
7	4 (Duplicate)	Yes
8	5	No
9	6	Unknown
10	7	Yes
11	8	Yes
12	9	Yes
13	10	Yes
14	10 (Duplicate)	Yes
15	11	Yes
16	11 (Duplicate)	Yes
17	12	Yes
18	12 (Duplicate)	Yes
19	13	Yes
20	14	Yes
21	15	No
22	16	No
23	16 (Duplicate)	No
24	17	Unknown
25	18	No
26	18 (Duplicate)	No
27	19	No
28	20	No
29	21	Unknown

Table 2. Parameters Used to Test GPS antennas

Freq (MHz)	Power Density (dBm/cm ²)	Duty Cycle (%)	PW (us)	Other
3250	29, 37, and 43	1.6	52	32 pulse burst Every 4 sec.
3250	43	3.2	52	32 pulse burst Every 4 sec.
920	18	3.5	125	None

3.0 METHODOLOGY

Each GPS antenna was determined to be working correctly and then the transmitter (source) was turned on and the GPS antenna was radiated (tested) for 10 minutes regardless of how it was affected, and the transmitter was then turned off. If the GPS antenna had been affected by the source, it was allowed 5 minutes to recover. If the antenna had apparently failed and didn't recover in 5 minutes after the source was turned off, the power to the antenna was turned off and back on. If it recovered it was called a "hard recoverable failure." If it didn't recover it was called a "hard non-recoverable failure." If a hard non-recoverable failure occurred, and a duplicate was on hand, it was not tested during the S-Band testing and saved for the L-Band testing. The procedure to enable recovery was referred to as a "hard reset." If the antenna was affected during the course of the 10-minute test, but recovered during the test or within 5 minutes after the source was turned off, it was referred to as a "soft failure."

4.0 TEST DATA

The listed antennas in Table 1 were subjected to the parameters specified in Table 2. Tables 3 through 7 describe how the antennas responded to the respective parameters. Figure 1 shows an antenna being tested at the power densities described in Tables 3 through 6. Figure 2 shows the L-Band antenna used in the L-Band test described in Table 7.

Table 3. S-Band Radar Test At 29 dBm/cm²

Test Parameters			
PW = 52 us			
32 Pulse Burst Every 4 seconds at Duty Cycle of 1.6 % For 10 minutes			
Freq (MHz)	Power Density (dBm/cm ²)	GPS Antenna	Comments [*] Source: S-Band Radar
3250	29	1	Normal display. Operation didn't appear to be affected.
		2	Normal display. Operation didn't appear to be affected.
		2D	Normal display. Operation didn't appear to be affected.
		3	Normal display. Operation didn't appear to be affected.
		3D	Normal display. Operation didn't appear to be affected.
		4	Normal display. Operation didn't appear to be affected.
		4D	Normal display. Operation didn't appear to be affected.
		5	Normal display. Operation didn't appear to be affected.
		6	Normal display. Operation didn't appear to be affected.
		7	Normal display. Operation didn't appear to be affected.
		8	Normal display. Operation didn't appear to be affected.
		9	Normal display. Operation didn't appear to be affected.
		10	Normal display. Operation didn't appear to be affected.
		10D	Normal display. Operation didn't appear to be affected.
		11	Normal display. Operation didn't appear to be affected.
		11D	Hard non-recoverable failure. (No lock in 21 sec.)
		12	Soft failure. (No lock in 5 sec. Recovered 4 min. into 10 min. test.)
		12D	Soft failure. (No lock in 5 sec. Recovered 2 min. 30 sec. into 10 min. test.)
		13	Normal display. Operation didn't appear to be affected.
		14	Normal display. Operation didn't appear to be affected.
		15	Normal display. Operation didn't appear to be affected.
16	Normal display. Operation didn't appear to be affected.		
16D	Normal display. Operation didn't appear to be affected.		
17	Normal display. Operation didn't appear to be affected.		
18	Normal display. Operation didn't appear to be affected.		
18D	Normal display. Operation didn't appear to be affected.		
19	Normal display. Operation didn't appear to be affected.		
20	Normal display. Operation didn't appear to be affected.		
21	Normal display. Operation didn't appear to be affected.		

* Green - Normal, Red - Hard Non-Recoverable Failure, Orange – Hard Recoverable Failure, and Yellow - Soft Failure.

Table 4. S-Band Radar Test At 37 dBm/cm²

Test Parameters			
PW = 52 us			
32 Pulse Burst Every 4 seconds at Duty Cycle of 1.6 % For 10 minutes			
Freq (MHz)	Power Density (dBm/cm ²)	GPS Antenna	Comments [*] Source: S-Band Radar
3250	37	1	Normal display. Operation didn't appear to be affected.
		2	Normal display. Operation didn't appear to be affected.
		2D	Normal display. Operation didn't appear to be affected.
		3	Normal display. Operation didn't appear to be affected.
		3D	Normal display. Operation didn't appear to be affected.
		4	Soft failure. (No lock within 8 sec. Recovered within 1 min. after source turned off).
		4D	Soft failure. (No lock within 8 sec. Recovered 1 min. after source off).
		5	Normal display. Operation didn't appear to be affected.
		6	Soft failure (No lock within 5 sec. Recovered 10 sec. after source off).
		7	Normal display. Operation didn't appear to be affected.
		8	Normal display. Operation didn't appear to be affected.
		9	Normal display. Operation didn't appear to be affected.
		10	Normal display. Operation didn't appear to be affected.
		10D	Normal display. Operation didn't appear to be affected.
		11	Soft failure. (No lock within 10 sec. Recovered within 1 min. and 30 sec. after source turned off.)
		11D	See Table 3.
		12	Normal display. Operation didn't appear to be affected.
		12D	Soft failure. (No lock in 2 sec. Recovered in 15 sec. after source off.)
		13	Normal display. Operation didn't appear to be affected.
		14	Normal display. Operation didn't appear to be affected.
		15	Normal display. Operation didn't appear to be affected.
16	Hard recoverable failure. See Antenna 16 in Section 5.2		
16D	Not tested because duplicate didn't recover in 5 min.		
17	Normal display. Operation didn't appear to be affected.		
18	Normal display. Operation didn't appear to be affected.		
18D	Normal display. Operation didn't appear to be affected.		
19	Normal display. Operation didn't appear to be affected.		
20	Normal display. Operation didn't appear to be affected.		
21	Normal display. Operation didn't appear to be affected.		

* Green - Normal, Red - Hard Non-Recoverable Failure, Orange – Hard Recoverable Failure, and Yellow - Soft Failure.

Table 5. S-Band Radar at 43 dBm/cm² (1.6 % Duty Cycle)

Test Parameters			
PW=52 us, 32 Pulse Burst Every 4 seconds at Duty Cycle of 1.6 % For 10 minutes			
Freq (MHz)	Power Density (dBm/cm²)	GPS Antenna	Comments Source: S-Band Radar
3250	43	1	Normal display. Operation didn't appear to be affected.
		2	Normal display. Operation didn't appear to be affected.
		2D	Normal display. Operation didn't appear to be affected.
		3	Soft failure. (DGPS indicator on receiver went out after 5 sec. but came back within 5 sec. of turning off source.)
		3D	Normal display. Operation didn't appear to be affected.
		4	Soft failure. (No lock 6 sec. into test. Recovered 1 min. and 7 sec. after source off.)
		4D	Soft failure. (No lock 2 sec. into test. Recovered 55 sec. after source off.)
		5	Hard non-recoverable failure. (No lock 1 min. into test.)
		6	Soft failure. (No lock 3 sec. into test. Recovered 10 sec. after source off.)
		7	Normal display. Operation didn't appear to be affected.
		8	Normal display. Operation didn't appear to be affected.
		9	Normal display. Operation didn't appear to be affected.
		10	Normal display. Operation didn't appear to be affected.
		10D	Soft failure. (No lock 2 sec. into test. Recovered 30 sec. after source off.)
		11	Soft failure. (No lock 6 sec. into test. Recovered 17 sec. after source off.)
		11D	See Table 3.
		12	Hard recoverable failure. (No lock 5 sec. into test.)
		12D	Soft failure. (No lock 3 sec. into test. Recovered 19 sec. after source off.)
		13	Normal display. Operation didn't appear to be affected.
		14	Normal display. Operation didn't appear to be affected.
		15	Normal display. Operation didn't appear to be affected.
16	See Table 4		
16D	N/A		
17	Normal display. Operation didn't appear to be affected.		
18	Normal display. Operation didn't appear to be affected.		
18D	Normal display. Operation didn't appear to be affected.		
19	Normal display. Operation didn't appear to be affected.		
20	Normal display. Operation didn't appear to be affected.		
21	Normal display. Operation didn't appear to be affected.		

* Green - Normal, Red - Hard Non-Recoverable Failure, Orange – Hard Recoverable Failure, and Yellow - Soft Failure.

Table 6. S-Band Radar at 43 dBm/cm² (3.2 % Duty Cycle)

Test Parameters			
PW = 52 us			
32 Pulse Burst Every 4 seconds at Duty Cycle of 3.2 % For 10 minutes			
Freq (MHz)	Power Density (dBm/cm ²)	GPS Antenna	Comments * Source: S-Band Radar
3250	43	1	Normal display. Operation didn't appear to be affected.
		2	Normal display. Operation didn't appear to be affected.
		2D	Not Tested
		3	Soft failure. (DGPS indicator on receiver blinked on and off but came back solid within 2 sec. of turning off source.)
		3D	Not Tested
		4	Soft failure. (No lock 5 sec. into test. Recovered 45 sec. after source off.)
		4D	Soft failure. (No lock 3 sec. into test. Recovered 1 min. 5 sec. after source off.)
		5	See Table 5.
		6	Soft failure. (No lock 3 sec. into test. Recovered 4 min. after source off.)
		7	Normal display. Operation didn't appear to be affected.
		8	Normal display. Operation didn't appear to be affected.
		9	Normal display. Operation didn't appear to be affected.
		10	Normal display. Operation didn't appear to be affected.
		10D	Normal display. Operation didn't appear to be affected.
		11	Soft failure. (No lock 6 sec. into test. Recovered 20 sec. after source off.)
		11D	See Table 3
		12	Hard recoverable failure. (No lock 5 sec. into test.)
		12D	Soft failure. (No lock 5 sec. into test. Recovered within 1 min. after source turned off.)
		13	Normal display. Operation didn't appear to be affected.
		14	Normal display. Operation didn't appear to be affected.
		15	Not Working
16	See Table 4		
16D	Not tested because Duplicate didn't recover in Table 4		
17	Normal display. Operation didn't appear to be affected.		
18	Normal display. Operation didn't appear to be affected.		
18D	Normal display. Operation didn't appear to be affected.		
19	Normal display. Operation didn't appear to be affected.		
20	Normal display. Operation didn't appear to be affected.		
21	Normal display. Operation didn't appear to be affected.		

* Green - Normal, Red - Hard Non-Recoverable Failure, Orange – Hard Recoverable Failure, and Yellow - Soft Failure.

Table 7. L-Band Radar at 18 dBm/cm² (3.5 % Duty Cycle)

Test Parameters			
PW = 125 us			
Duty Cycle of 3.5 % For 10 minutes			
Freq (MHz)	Power Density (dBm/cm²)	GPS Antenna	Comments Source: L-Band Radar
920	18	1	Normal display. Operation didn't appear to be affected.
		2	Not Tested
		2D	Normal display. Operation didn't appear to be affected.
		3	Normal display. Operation didn't appear to be affected.
		3D	Normal display. Operation didn't appear to be affected.
		4	Not Tested
		4D	Soft failure. (No lock 5 min. 40 sec. into test. Recovered at 7 min. 10 sec. into test.)
		5	See Table 5
		6	Normal display. Operation didn't appear to be affected.
		7	Normal display. Operation didn't appear to be affected.
		8	Normal display. Operation didn't appear to be affected.
		9	Normal display. Operation didn't appear to be affected.
		10	Normal display. Operation didn't appear to be affected.
		10D	Not Tested
		11	Hard recoverable failure. (No lock immediately.)
		11D	See Table 3.
		12	Hard recoverable failure. (No lock 5 sec. into test.)
		12D	Not Tested
		13	Hard recoverable failure. (No lock immediately.)
		14	Normal display. Operation didn't appear to be affected.
		15	Not Working (Dropped at beginning of L-Band Test)
16	Not Tested		
16D	Hard recoverable failure. (No lock 3 sec. into test.)		
17	Normal display. Operation didn't appear to be affected.		
18	Normal display. Operation didn't appear to be affected.		
18D	Not Tested		
19	Normal display. Operation didn't appear to be affected.		
20	Normal display. Operation didn't appear to be affected.		
21	Normal display. Operation didn't appear to be affected.		

* Green - Normal, Red - Hard Non-Recoverable Failure, Orange – Hard Recoverable Failure, and Yellow - Soft Failure.



Figure 1. S-Band Antenna Radiating GPS Antenna



Figure 2. L-Band Horn Used to Radiated GPS Antennas

5.0 TEST RESULTS

The test results are described as follows:

5.1 Anomalies in Table 3 were as follows:

- Antenna 11D indicated a no lock within seconds into the test, and did not recover after 5 minutes. It was determined to be a hard non-recoverable failure.
- Antenna 12 indicated a no lock condition within seconds into the test, but recovered 4 minutes into the test, and performed normally for the rest of the 10-minute test. It was considered a soft failure.
- Antenna 12D indicated a no lock condition within seconds into the test, but recovered 2 minutes and 30 seconds into the test, and performed normally for the rest of the 10-minute test. It was considered a soft failure.

5.2 Anomalies in Table 4 were as follows:

- Antenna 4 indicated a no lock condition within seconds into the test. It recovered within 1 minute after the source was turned off. It was considered a soft failure.
- Antenna 4D indicated a no lock condition within seconds into the test. It recovered within 1 minute after the source was turned off. It was considered a soft failure.
- Antenna 6 indicated a no lock condition within seconds into the test. It recovered within 10 seconds after the source was turned off. It was considered a soft failure.
- Antenna 11 indicated a no lock condition within seconds into the test. It recovered within 1 minute and 30 seconds after the source was turned off. It was considered a soft failure.
- Antenna 12D indicated a no lock condition within seconds into the test. It recovered within 15 seconds after the source was turned off. It was considered a soft failure.
- Antenna 16 indicated a no lock condition within seconds into the test. It did not recover within the allotted 5 minutes after the source was turned off. Later, when L-Band testing was performed it was determined that Antenna 16 was a hard recoverable fault rather than a hard non-recoverable fault. Hence, it was not tested at 43 dBm/cm².

5.3 Anomalies in Table 5 were as follows:

- Antenna 3's DGPS indicator on its receiver went out within seconds into the test, and came back on 5 seconds after the source was turned off. It was considered a soft failure.
- Antenna 4 indicated a no lock condition within seconds into the test. It recovered within 1 minute and 7 seconds after the source was turned off. It was considered a soft failure.

- Antenna 4D indicated a no lock condition within seconds into the test. It recovered within 55 seconds after the source was turned off. It was considered a soft failure.
- Antenna 5 indicated a no lock condition 1 minute into the test. It did not recover within the allotted 5 minutes after the source was turned off. It was considered to be a hard non-recoverable failure.
- Antenna 6 indicated a no lock condition within seconds into the test. It recovered within 10 seconds after the source was turned off. It was considered a soft failure.
- Antenna 10D indicated a no lock condition within seconds into the test. It recovered within 30 seconds after the source was turned off. It was considered a soft failure.
- Antenna 11 indicated a no lock condition within seconds into the test. It recovered within 10 seconds after the source was turned off. It was considered a soft failure.
- Antenna 12 indicated a no lock condition within seconds into the test. It did not recover within 5 minutes after the source was turned off. After a hard reset, it recovered, and was considered to be a hard recoverable failure.
- Antenna 12D indicated a no lock condition within seconds into the test. It recovered within 10 seconds after the source was turned off. It was considered a soft failure.

5.4 Anomalies in Table 6 were as follows:

- Antenna 3's DGPS indicator on the receiver went out within seconds into the test, and came back on 5 seconds after the source was turned off. It was considered a soft failure.
- Antenna 4 indicated a no lock condition within seconds into the test. It recovered within 1 minute and 7 seconds after the source was turned off. It was considered a soft failure.
- Antenna 4D indicated a no lock condition within seconds into the test. It recovered within 55 seconds after the source was turned off. It was considered a soft failure.
- Antenna 6 indicated a no lock condition within seconds into the test. It recovered within 10 seconds after the source was turned off. It was considered a soft failure.
- Antenna 11 indicated a no lock condition within seconds into the test. It recovered within 20 seconds after the source was turned off. It was considered a soft failure.
- Antenna 12 indicated a no lock condition within seconds into the test. It did not recover within 5 minutes after the source was turned off. After a hard reset, it recovered, and was considered to be a hard recoverable failure.
- Antenna 12D indicated a no lock condition within seconds into the test. It recovered within 10 seconds after the source was turned off. It was considered a soft failure.

5.5 Anomalies in Table 7 were as follows:

- Antenna 4D indicated a no lock condition 5 minutes 40 seconds into the test. It recovered 7 minutes 10 seconds into the test. It was considered a soft failure.
- Antenna 11 indicated a no lock within seconds into the test. It did not recover within 5 minutes after the source was turned off. It recovered after a hard reset, and was considered to be a hard recoverable failure.
- Antenna 12 indicated a no lock within seconds into the test. It did not recover within 5 minutes after the source was turned off. It recovered after a hard reset, and was considered to be a hard recoverable failure.
- Antenna 13 indicated a no lock within seconds into the test. It did not recover within 5 minutes after the source was turned off. It recovered after a hard reset, and was considered to be a hard recoverable failure.
- Antenna 16D indicated a no lock within seconds into the test. It did not recover within 5 minutes after the source was turned off. It recovered after a hard reset, and was considered to be a hard recoverable failure.

Note: When there were two antennas with the same model number, only one was tested at L-Band due to time limitations.

6.0 SUMMARY

At S-Band (duty cycle = 1.6%) with a power density of 29 dBm/cm², one IMO compliant antenna had a hard non-recoverable failure, and two IMO compliant antennas had soft failures.

At S-Band (duty cycle = 1.6%) with a power density of 37 dBm/cm², one IMO non-compliant antenna had a hard recoverable failure, four IMO compliant antennas had soft failures, and one antenna with unknown IMO compliance had a soft failure.

At S-Band (duty cycle = 1.6%) with a power density of 43 dBm/cm², one IMO non-compliant antenna had a hard recoverable failure, one IMO compliant antenna had a hard recoverable failure, six IMO compliant antennas had soft failures, and one antenna with unknown IMO compliance had a soft failure.

At S-Band (duty cycle = 3.2 %) with a power density of 43 dBm/cm², one IMO compliant antenna had a hard recoverable failure, six IMO compliant antennas had soft failures, and one antenna with unknown IMO compliance had a soft failure.

At L-Band (duty cycle = 3.5 %) with a power density of 18 dBm/cm², three IMO compliant antennas had a hard recoverable failure, one IMO non-compliant antenna had a hard recoverable failure, and one IMO compliant antennas had a soft failure.

These results are also summarized in Table 8.

Table 8. Summary of GPS Antenna Test Results

GPS Ant.	IMO Compliant?	Freq. = 3250 MHz (S-Band)				Freq.=920 MHz (L-Band)
		Duty Cycle (D C) = 1.6 %		D C = 3.2 %		D C = 3.5 %
		Power Density (dBm/cm ²)				
		29	37	43	43	18
1	No	NE	NE	NE	NE	NE
2	No	NE	NE	NE	NE	Not Tested
2D	No	NE	NE	NE	NE	NE
3	Yes	NE	NE	SF	SF	Not Tested
3D	Yes	NE	NE	NE	NE	NE
4	Yes	NE	SF	SF	SF	Not Tested
4D	Yes	NE	SF	SF	SF	SF
5	No	NE	NE	HNRF		S-Band Failure
6	Unknown	NE	SF	SF	SF	NE
7	Yes	NE	NE	NE	NE	NE
8	Yes	NE	NE	NE	NE	NE
9	Yes	NE	NE	NE	NE	NE
10	Yes	NE	NE	NE	NE	NE
10D	Yes	NE	NE	SF	SF	Not Tested
11	Yes	NE	SF	SF	SF	HRF
11D	Yes	HNRF				S-Band Failure
12	Yes	SF	NE	HRF	HRF	HRF
12D	Yes	SF	SF	SF	SF	Not Tested
13	Yes	NE	NE	NE	NE	HRF
14	Yes	NE	NE	NE	NE	NE
15	No	NE	NE	NE	Not Working	Not Working
16	No	NE	HRF	Not Tested	Not Tested	Not Tested
16D	No	NE	Not Tested	Not Tested	Not Tested	HRF
17	Unknown	NE	NE	NE	NE	NE
18	No	NE	NE	NE	NE	NE
18D	No	NE	NE	NE	NE	Not Tested
19	No	NE	NE	NE	NE	NE
20	No	NE	NE	NE	NE	NE
21	Unknown	NE	NE	NE	NE	NE

Key: NE – No Effect -
 SF – Soft Failure -
 HNRF – Hard Non-Recoverable Failure -
 HRF – Hard Recoverable Failure -

APPENDIX A

GPS ANTENNA GROUND PLANE TEST

A.1 OBJECTIVE

High power radars are believed to be responsible for the burnout of active commercial GPS antennas. Therefore, NSWCCD, in conjunction with the USCG, has scheduled testing to address the GPS shipboard electromagnetic interference (EMI)/burnout problem at specified power densities (PDs).

A.2 APPROACH

Subject each GPS antenna to specified PD employing given test parameters, and document the antenna response.

A.3 SAFETY

The Standing Operating Procedures (SOPs) for safety will be adhered to as outlined in Appendix B.

A.4 METHODOLOGY

Each GPS antenna will be tested as follows:

A.4.1 Microwave Calibration Technique

The test EME will be calibrated and measured utilizing the set-up in Figure A-1. The radio frequency (RF) signal source will be turned on and the distance that yields the desired PD shall be determined and marked. The PD will be double checked with a portable power meter.

A.5 TEST SET-UP

Each GPS antenna will be placed the appropriate distance from the source antenna. Figure A-2 depicts the test set-up for microwave testing, but the test set-up for high frequency (HF) is similar.

The GPS antenna transmission line will go to its display unit through a bulkhead connector so that the shield on its transmission line will be grounded (when a shield is present). This will help protect the display unit from being affected by RF currents present on the shield of the transmission line. This is more significant for lower frequencies such as HF.

The test conductor shall ensure that the GPS display is operating normally. Then the GPS antenna shall be subjected to the appropriate power density for the allotted amount of time, and then secured. The GPS display shall be checked to ascertain if it is still operating normally. Appropriate notes will be taken, and the next GPS antenna measurement made.

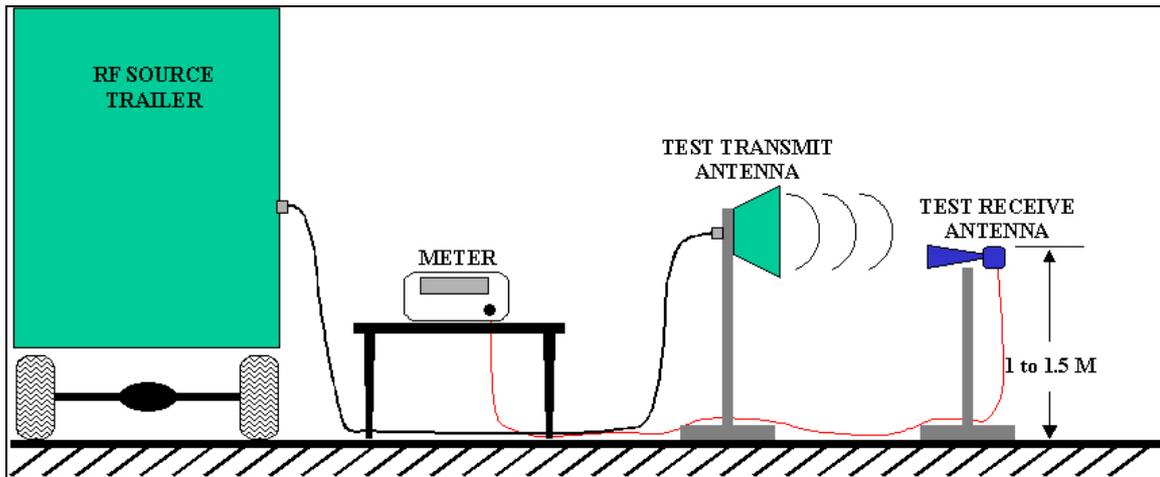


Figure A-1. Microwave Calibration Technique

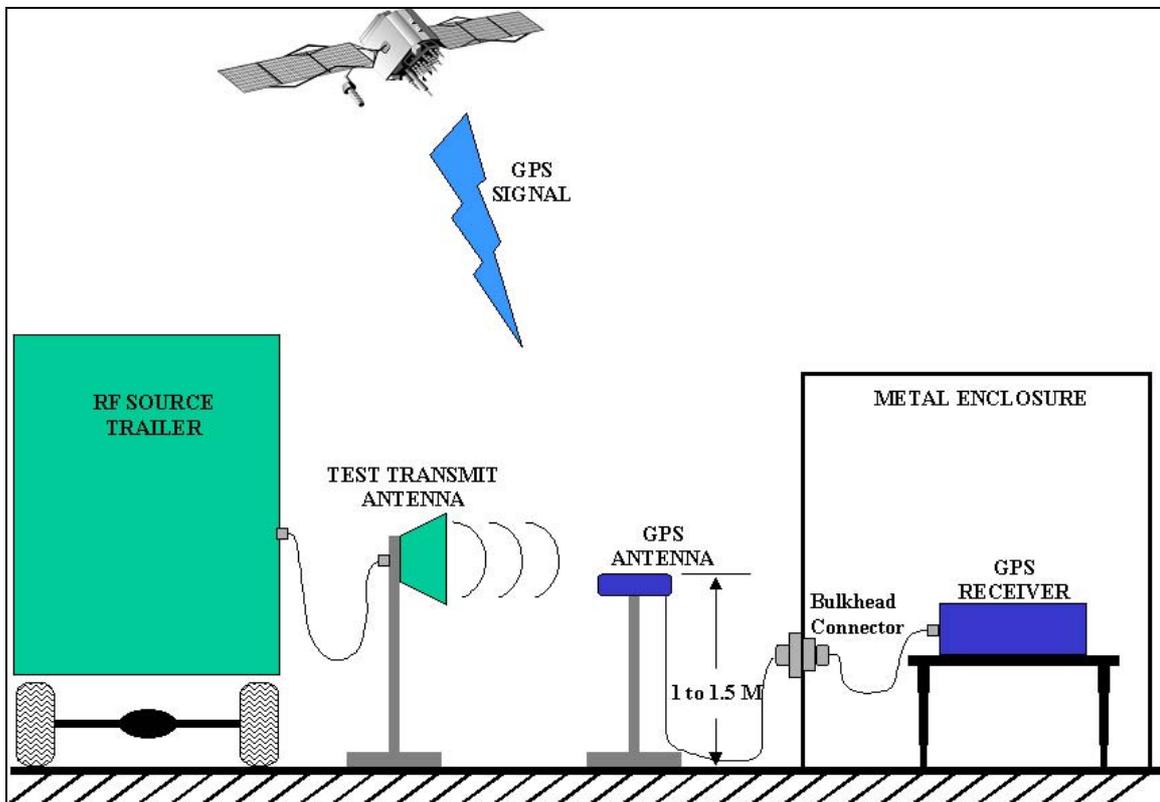


Figure A-2. Test Set-Up Configuration

APPENDIX B
SAFETY PRECAUTIONS
AND
STANDARD OPERATING PROCEDURES (SOPs)

B.1 SAFETY PRECAUTIONS AND STANDARD OPERATING PROCEDURES (SOPS)

The Hazards of Electromagnetic Radiation to Ordnance (HERO) ground plane general safety precautions and SOPs are provided in Reference 1. All test personnel will be fully familiar with the safety precautions and SOPs contained in Reference 1, 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 transmitters will be operated by NSWCCD personnel or government contractors. When the transmitters are operating, personnel will be restricted from approaching the transmitting antennas. A blue or red strobe light will be illuminated when the transmitters are radiating, and plastic safety chains with "RF HAZARDS" signs will be used to cordon off restricted areas. Access will be controlled and monitored by on-deck personnel.

In accordance with Reference 2, body-contact current and body-to-ground current will be measured before commencing the tests to protect test personnel from any hazards of electromagnetic radiation (EMR). The test EME power levels will be limited and monitored throughout the test to ensure that body-contact current and body-to-ground current do not exceed the standards in Reference 2.

The following safety precautions and practices will be strictly adhered to throughout the HERO test.

No personnel shall be exposed to an electromagnetic field whose energy exceeds the permissible levels prescribed in Reference 2. The test director will use a field probe to monitor the real-time average E-field exposure of test personnel.

No personnel shall pass closer than 10 feet of a HF antenna while it is transmitting. All non-essential personnel shall remain at a minimum distance of 50 feet from the HF antenna while it is transmitting.

No personnel shall pass between a radiating antenna and the system under test.

The test director shall maintain continuous visual and radio communications with the transmitter operator. If any person appears to be approaching the antenna during transmission without clearly stating his/her intentions, the transmitter operator shall turn the transmitter off.

One or more emergency transmitter shutdown signals shall be established, one of which shall be visible.

All non-essential personnel shall be directed to safe areas away from the transmitting antenna prior to any transmissions.

In order to protect personnel from potential RF hazards, the perimeter of the hazardous area shall be cordoned off and identified with signs warning of EMR hazards. In addition, all test personnel shall continuously monitor the test area for the presence of unauthorized personnel.

Aircraft and government-furnished equipment fuel tanks shall be topped off to 75% of capacity at the beginning of each day of HERO testing, or shall be purged.

All aircraft systems activated by EIDs not qualified HERO SAFE shall have these devices rendered inert or safe, or removed before testing.

All armament shall remain in a "safe" status at all times during testing.

All transmitter operators and technicians shall use the "buddy" system when working on electrical equipment.

All test personnel shall be familiar with and understand the SOPs for safe conduct of all HERO testing utilizing the ground plane facilities.

No smoking or open flame shall be permitted within 50 feet of the system under test, aircraft, or fuel truck.

If a fire of any type occurs, the test will be stopped, and the fire department shall be notified immediately.

An industrial fire extinguisher must be available for use during the test.

If a fuel leak develops, the test director shall contact the appropriate maintenance control to resolve the problem.

The test area shall be inspected daily for any flammable material and liquids prior to testing.

The test area shall be cleared of all RF-susceptible equipment. If such equipment must remain, a power-down test may be necessary.

In addition to the precautions listed here, the test director shall advise all test personnel of any unusual safety precautions connected with the test.

B.2 REFERENCES

1. NSWCDD/J52, SOP J52-702-01-A of 13 Feb 01, Subj: Hazards of Electromagnetic Radiation to Ordnance (HERO)/Electromagnetic Vulnerability (EMV) Testing Standard Operating Procedures at Ground Plane Facilities, Dahlgren, VA.
 2. DoDINST 6055.11 of 21 Feb 95, Protection of DoD Personnel from Exposure to Radio Frequency Radiation and Military Exempt Lasers.
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