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Evaluation of Marine VHF Radios: Compliance to IEC Receiver Standards

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Executive Summary

The maritime mobile frequency band supports maritime communications worldwide. Appendix 18 of the ITU Radio Regulations (RR) defines the channels of the maritime mobile service. These channels support a variety of communication functions including: public correspondence, intership and ship-to-coast, coast-to-ship, port operations, calling and various safety purposes. Safety functions include distress, search and rescue, ship movement, navigation (bridge-to-bridge) communications, and maritime safety information broadcasts.

Mariners in the United States and other countries are experiencing interference on channels allocated to the above functions. The Radio Technical Commission for Maritime Services (RTCM) established Special Committee 117 to investigate the interference and determine if the International Electrotechnical (IEC) standard 1097-7 "*Global Maritime Distress and Safety System (GMDSS)-Part 7: Shipborne VHF Radiotelephone Transmitter and Receiver-Operational and Performance Requirements, Methods of Testing and Required Test Results*" would be sufficient to protect marine VHF radios from interference. In support of this effort, NTIA, in coordination with the Coast Guard and RTCM SC-117, undertook a task to test nine commercial and recreational grade marine VHF radios to the IEC standard and perform radiated test in areas where severe cases of interference are occurring. Laboratory testing of the radios to the IEC standard was performed in Boulder, Colorado. The radiated tests were performed in Savannah, Georgia o the Savannah River and on the Mississippi River in New Orleans, Louisiana. Mariners in both locations have been reporting cases of severe interference in the marine VHF band on the waterways for quite some time now. Some of the channels experiencing the interference are key channels used for safety and bridge-to-bridge communications. The interference is very disruptive to normal operations on the river and is distracting to the radio operators.

The IEC laboratory tests and radiated tests were based on receiver SINAD measurements. In the IEC 1097-7 test procedures, the SINAD of a receiver being tested was set to 20 dB by adjusting the desired signal power and then injecting interference into the circuit to reduce the SINAD to 14 dB. The resulting interference-to-signal radio (I/S) was then calculated in dB and compared to the minimum IEC requirement. The IEC test procedures were used to measure the receiver sensitivity and to calculate the receiver co-channel rejection ratio, adjacent channel selectivity, blocking (saturation) and intermodulation rejection ratio.

All of the radios easily exceeded the minimum receiver sensitivity requirement. Four radios failed the co-channel rejection ratio test and only two radios passed the adjacent channel selectivity test. In most cases the radios which failed were within 3-5 dB of passing the tests. The most important IEC tests, which are related to the complaints about interference in Savannah and New Orleans, were the intermodulation rejection radio and blocking tests. Four radios passed the intermodulation test while only one passed the blocking tests. Radio L, operating in local mode passed both tests and was the only radio to operate satisfactorily in New Orleans and Savannah. Radio L had an intermodulation rejection ratio of 81 dB while the IEC standard is 68 dB. Therefore, it can be concluded from the results of the IEC tests and radiated tests that the IEC intermodulation rejection ratio performance requirement is not stringent enough for radios operating in some US ports and waterways.

The results of these tests show that the Coast Guard and RTCM should consider the following items when developing a marine VHF radio receiver standard based on the IEC standard: the IEC 1097-7 test procedures and performance objectives do not adequately take into account the severe intermodulation and blocking interference that is occurring in major US ports and waterways such as Savannah and New Orleans, the receiver standards should be based on the power levels of the unwanted signals that have been measured in Savannah and New Orleans, and the intermodulation rejection ratio test should be referenced from s specific wanted signal power level and a minimum SINAD, rather than a receivers maximum usable sensitivity for a 20 dB SINAD.

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SECTION 1
INTRODUCTION

1.1 Background

NTIA published a report for the Coast Guard that studied the compatibility between 12.5 kHz and 25 kHz channelized marine VHF radios, NTIA TR-97-343 "*Assessment of Compatibility between 25 and 12.5 kHz Channelized Marine Radios*". One of the conclusions of the report was that the adoption of appropriate standards for marine VHF radio receivers would help alleviate problems due to congestion in the marine electromagnetic environment. Currently, the United States does not have receiver standards for marine VHF radios. An organization comprised of mariners, radio manufacturers, and frequency regulators, the Radio Technical Commission for Maritime services (RTCM), established RTCM SC-117 to investigate receiver standards developed by other regulatory agencies or organizations. One organization, the International Electrotechnical Commission (IEC), has recently published a document that contains proposed standards for marine VHF radios.

The IEC's standards for marine radios are in a document titled "*IEC 1097-7: Global Maritime Distress and Safety System (GMDSS)-Part 7: Shipborne VHF Radiotelephone Transmitter and Receiver-Operational and Performance Requirements, Methods of Testing and Required Test Results*".

The Coast Guard is interested in establishing voluntary standards, similar to the IEC standard, for marine VHF radios sold in the United States to help protect them from interference. In support of this effort, NTIA, in coordination with the Coast Guard and RTCM SC-117, undertook a task to test nine commercial and recreational grade marine VHF radios to the IEC standard and perform radiated tests in areas where severe cases of interference are occurring. Laboratory testing of the radios to the IEC standard was performed in Boulder, Colorado. The radiated tests were performed in Savannah, Georgia on the Savannah River and on the Mississippi River in New Orleans, Louisiana. These locations were chosen for "live" testing due to the numerous complaints from mariners that their communications are being disrupted on the Savannah and Mississippi Rivers due to interference in the marine VHF band.

The IEC laboratory procedures and standards are based on receiver SINAD measurements and Interference-to-signal (I/S) ratios. A receiver SINAD measurement is the ratio, expressed in dB, of the desired signal power to interference, noise, and distortion. An I/S ratio, expressed in dB, is the level of the unwanted signal to the wanted signal. In the IEC test procedures, the SINAD of a receiver being tested was set to 20 dB by adjusting the desired signal power and then injecting interference into the circuit to reduce the SINAD to 14 dB. The resulting interference-to-signal ratio (I/S) was then calculated in dB and compared to the minimum IEC requirement. The radio either passed or failed the test. The IEC test procedures were used to measure the receiver sensitivity and to calculate the receiver co-channel rejection ratio, adjacent channel selectivity, blocking (saturation) and intermodulation rejection ratio.

1.2 Test Objectives

The objective of these tests was to determine the marine VHF radios compliance to the performance standards for marine VHF radio receivers contained in IEC document 1097-7. The specific laboratory tests that were performed from IEC document 1097-7 are shown in Table 1-1.

Table 1-1

IEC Test
Section 5.5.3 Sensitivity
Section 5.5.4 Co-Channel Rejection Ratio
Section 5.5.5 Adjacent Channel Selectivity
Section 5.5.7 Intermodulation Response
Section 5.5.8 Blocking

1.3 Test Description

The radios were tested by using signal generators to provide the wanted and unwanted signals. The signals were combined with a RF network and then injected into the RF input of the radios. A communication test set was used for receiver SINAD measurements.

The first task of the tests was to determine the power required at the radio's RF input that would produce a 20 dB SINAD in the radio receiver. Each interference test used that as a starting point and then unwanted signal(s) were injected into the radio receiver to lower the SINAD to 14 dB. The power of the unwanted and wanted signals were then used to calculate an interference-to-signal (I/S) ratio in dB which was then compared to the IEC minimum test requirement. If the radio met or exceeded the requirement of the test that was being performed then it passed, otherwise it failed.

1.4 Test Radios

Commercially available analog 25 kHz channelized marine VHF FM radios were tested. These 25 kHz radios included four commercial grade radios representative of the type used by commercial boaters and government agencies.

Most recreational boaters use less expensive 25 kHz radios that retail for under 300 dollars. These types of radios, which were found to be more susceptible to interference, were also tested. NTIA purchased three fixed mount and two hand-held radios of these types from local retailers for testing.

The radios are identified by alphabetical code. Manufacturers' names and model numbers are not included in this report. The radios are categorized as either recreational or commercial grade radios and as either fixed-mount or handheld below in Table 1-2.

Table 1-2
Radio Description

Radio	Type	Grade
A	fixed-mount 25 kHz	recreational
B	fixed-mount 25 kHz	commercial
E	hand-held 25 kHz	recreational
F	fixed-mount 25 kHz	commercial
G	hand-held 25 kHz	recreational
H	fixed-mount 25 kHz	recreational
I	fixed-mount 25 kHz	recreational
K	fixed-mount 25 kHz	recreational
L	fixed-mount 25 kHz	commercial

Radio L had a local/distance switch for its receiver accessible on a front panel control which was separate from the squelch control. The local/distance switch is used by the radio operator to reduce the sensitivity of the radio receiver by about 10 dB to compensate for strong undesired signals in the electromagnetic environment. This radio was designed with these features for operations in congested EM environments.

SECTION 2
TEST RESULTS

2.1 Receiver Sensitivity

The IEC minimum requirement for this standard is 1 FV at the radio RF input for a 20 dB SINAD. This level is equal to -107 dBm into a 50 ohm load. The sensitivity of the radios was measured at channels 01A (156.050 MHz), 16 (156.800 MHz), 67 (156.375 MHz), 70 (156.525 MHz), and 87 (161.975 MHz). All of the radios met or exceeded the 1 FV requirement, including radio L operating in the local and distance modes. Table A-2 in Appendix A contains the measured data for the radio sensitivity tests.

2.2 Co-Channel Rejection Ratio

The IEC requirement for this standard is -10 to 0 dB, calculated as the ratio of the unwanted signal to wanted signal which would degrade the SINAD from 20 to 14 dB. Channel 67 was used as the wanted signal for this test. Radio G, H, I, K, and L met the requirement of this standard. Radios A, B, E, and F failed. Radios A and B failed by 1 dB while radio E failed by 2 dB and radio F failed by 4 dB. Table A-4 in Appendix A contains the measured data for the co-channel rejection ratio tests.

2.3 Adjacent Channel Selectivity

The IEC minimum requirement for this standard is 70 dB, calculated as the ratio of the unwanted signal to wanted signal which would degrade the SINAD from 20 to 14 dB. Channel 67 (156.375 MHz) was used as the wanted signal channel for this test and the unwanted signals were set at channel 8 (156.400 MHz) and channel 07A (156.350 MHz). Commercial grade Radios B and F passed this test. The only recreational grade radio to pass this test was radio K. Table A-3 in Appendix A contains the measured data for the radios adjacent channel selectivity test.

2.4 Intermodulation Rejection Ratio

The IEC minimum requirement for this standard is 68 dB, calculated as the ratio of unwanted signal to wanted signal which would degrade the SINAD from 20 to 14 dB. The unwanted signals are set to frequencies 50 kHz and 100 kHz removed from the wanted signal channel to generate a third order intermodulation product within the radio receiver on the wanted signal channel. Channel 67 was the wanted signal channel for this test and the unwanted signals were set at channels 68 (156.425 MHz) and channel 69 (156.475 MHz). The power of the unwanted signals at the radio RF input were set to equal levels.

Radios B, F, H, and L passed this test. Radio L was the best performer and passed the test by 18 dB with the receiver operating in distance mode and by 16 dB operating in local mode. Table A-5 in Appendix A contains the measured data for the radio intermodulation tests. The results of this test are important because this is the type of interference that is occurring at New Orleans and Savannah.

The frequency separation between the wanted signal and the unwanted signals (50 and 100 kHz) was seen to generate interference effects other than intermodulation products within the radio receiver. This topic is discussed below.

Further investigation of this test revealed that in some instances the reduction in the SINAD was not totally due to an intermodulation product, but also included adjacent channel interference effects as well. This was verified by turning off the RF output of each of the unwanted signal generators one at a time. With only one unwanted signal connected into the test circuit the intermodulation product could not be generated and the SINAD should have recovered to approximately 20 dB. In some cases when the unwanted signal on channel 68 was transmitting into the circuit and the unwanted signal on channel 69 was not, the SINAD did not recover to 20 dB. When the situation was reversed the SINAD generally recovered to a higher value. This result indicated that adjacent channel interference was also contributing to the SINAD reduction and that the effect was more pronounced with the closest unwanted signal (channel 68) operating in the circuit. The level of this effect varied with each radio.

Additional tests on radio L showed that as the frequency separation between the wanted signal and unwanted signals increased, the SINAD recovered to a higher value indicating that the adjacent channel effects were becoming less of a factor. The “break point” is the amount of frequency separation between the wanted signal channel and the unwanted signals where the reduction in the SINAD is a result of the intermodulation product and not adjacent channel interference.

2.5 Blocking

The IEC requirement for this standard is 90 dBFV (emf), which would degrade the SINAD to 14 dB. This level equates to a power of -23 dBm at the RF input of the test radio. Channel 67 was used as the desired signal channel for this test. The unwanted signal was set at frequencies of "10, "5, "2, and "1 MHz from channel 67 for this test.

The only radio that was able to pass this test for the entire frequency range was radio L operating in local mode. The other radios were able to pass the test at the far frequencies but failed as the unwanted signal was within "2 MHz and "1 MHz of the wanted signal. Radio L had the best overall performance while operating in local mode. This radio was able to take up to -14 dBm of unwanted signal power, which is 9 dB above the IEC requirement, and still meet the IEC sensitivity requirement. Tables A-6 and A-7 in Appendix A contain the measured data for the radio blocking tests.

2.6 Summary

The commercial grade radios performed better than the recreational grade radios by passing more of the test requirements. None of the radios were able to pass all of the tests. The best performer was Radio L. Operating in local mode it passed all of the tests except for the adjacent channel selectivity test. The results show that the blocking test requirement was the hardest test for the radios to pass. This test is very important because blocking type interference is occurring in US ports and waterways and the measured levels of the unwanted signals exceed the IEC requirement by 8 dB.

SECTION 3
CONCLUSIONS and RECOMMENDATIONS

The following conclusions and recommendations can be drawn from the results of IEC 1097-7 tests performed on the radios in the laboratory. The performance requirements of the IEC tests were evaluated by the radiated testing which was performed on the Mississippi River in New Orleans, Louisiana and the Savannah River in Savannah Georgia. The results of the radiated tests are discussed in NTIA Report 99-362.

3. Conclusions

1.The marine radios that were tested, which are typical of the types sold to recreational boaters and commercial mariners, easily met or exceeded the IEC minimum receiver sensitivity requirement of 1 FV (for a 20 dB SINAD).

2. Except for radio L operating in local mode, radios that passed the IEC intermodulation rejection ratio test of 68 dB were still susceptible to intermodulation interference at Savannah and New Orleans. Therefore, the performance requirement of the intermodulation rejection ratio test set by IEC is not stringent enough for marine radios operating in/near major US ports and waterways.

3.In some radios, the 50 kHz and 100 kHz spacing between the wanted and unwanted signals for the intermodulation rejection ratio test resulted in adjacent channel interference occurring along with the intermodulation interference. The adjacent channel interference further reduced the SINAD measurement and affected the results of the intermodulation rejection ratio test.

4.Referencing the unwanted signal power levels in the IEC intermodulation rejection ratio test to the maximum usable receiver sensitivity results in the unwanted signal power levels being lower than those measured in New Orleans and Savannah because the receivers have sensitivities that far exceed the IEC requirement of 1 FV.

3.1 Recommendations

It is recommended that the Coast Guard and RTCM consider the following items when developing a VHF marine radio receiver standard.

1. The IEC 1097-7 test procedures and performance objectives do not adequately take into account the severe intermodulation and blocking interference that is occurring in major US ports and waterways, such as Savannah and New Orleans.

2.A VHF marine radio receiver standard developed by the Coast Guard and RTCM should be based on the power levels of the unwanted signals that have been measured in Savannah and New Orleans.

3. A VHF marine radio receiver standard developed by the Coast Guard and RTCM should reference the intermodulation rejection ratio test from a specific wanted signal power level and a minimum SINAD, rather than the IEC procedure which is based on a receivers maximum usable sensitivity for a 20 dB SINAD .

Appendix A
Measured Data

This appendix contains the measured data that was recorded for each radios laboratory tests and the I/S ratios that were calculated using that data. A summary pass/fail table is shown below in Table A-1. The recorded data on each test is presented in the following tables: Table A-2 Sensitivity tests, Table A-3 Adjacent Channel Interference tests, Table A-4 Co-Channel interference Tests, Table A-5 Intermodulation Interference Tests, and Tables A-6 and A-7 Blocking Tests. Radio L has data entries for local and distance mode operation. The power of the unwanted signals is measured at the RF input of the test radios for all tests.

Table A-1

Radio	**IEC Test**				
	5.5.3 Sensitivity	**5.5.4 Co-Channel Rejection**	**5.5.5 Adjacent Channel Selectivity**	**5.5.7 Intermodulation Response**	**5.5.8 Blocking**
A	pass	fail	fail	pass	fail
B	pass	fail	pass	pass	fail
E	pass	fail	fail	fail	fail
F	pass	fail	pass	pass	fail
G	pass	pass	fail	fail	fail
H	pass	pass	fail	pass	fail
I	pass	pass	fail	pass	fail
K	pass	pass	pass	fail	fail
L Distance Local	pass pass	pass pass	fail fail	pass pass	fail pass

IEC 5.5.3 Sensitivity

The IEC sensitivity requirement is 1FV at the RF input of the radio that would produce a 20 dB SINAD. This equates to a power level of -107 dBm at the RF input of the test radio.

Table A-2
Sensitivity Test Measured Data

radio	Sensitivity (dBm)	pass/fail
A	-113	pass
B	-120	pass
E	-115	pass
F	-116	pass
G	-116	pass
H	-114	pass
I	-116	pass
K	-116	pass
L Distance Local	-117 -107	pass pass

IEC 5.5.5 Adjacent Channel Selectivity

The IEC requirement for adjacent channel selectivity is 70 dB, calculated as the level of the unwanted signal to the level of the wanted signal which degrades the receiver SINAD from 20 to 14 dB.

Table A-3
Adjacent channel Interference Test Measured Data

radio	Sensitivity (dBm)	-25 kHz Off-tuned interferer (dBm)	I/S (dB)	+25 kHz Off-tuned Interferer (dBm)	I/S (dB)	pass/fail
A	-113	-45	68	-44	69	fail
B	-120	-47	73	-44	76	pass
E	-115	-48	67	-49	66	fail
F	-116	-38	78	-39	77	pass
G	-116	-58	58	-57	59	fail
H	-114	-47	67	-44	70	fail
I	-116	-47	69	-46	70	fail
K	-116	-45	71	-44	72	pass
L Distance Local	-117 -107	-68 -59	49 48	-67 -58	50 49	fail fail

IEC 5.5.4 Co-Channel Rejection Ratio

The IEC requirement for the Co-Channel rejection ratio -10 to 0 dB, calculated as the level of the unwanted signal to the level of the wanted signal which degrades the receiver SINAD from 20 to 14 dB.

Table A-4
Co-Channel Test Measured Data

radio	Sensitivity (dBm)	Interferer (dBm)	I/S (dB)	pass/fail
A	-113	-124	-11	fail
B	-120	-131	-11	fail
E	-115	-127	-12	fail
F	-116	-130	-14	fail
G	-116	-125	-9	pass
H	-114	-122	-8	pass
I	-116	-124	-8	pass
K	-116	-125	-9	pass
L Distance	-117	-124	-7	pass
Local	-107	-115	-8	pass

IEC 5.5.7 Intermodulation Rejection Ratio

The IEC requirement for intermodulation rejection ratio is 68 dB, calculated as the ratio of the unwanted signal to the level of the wanted signal which degrades the receiver SINAD from 20 to 14 dB.

Table A-5
Intermodulation Test Measured Data

radio	S, (dBm)	I_1 and I_2 (dBm)	I/S ratio (dB)	pass/fail
A	-113	-46	67	fail
B	-120	-48	72	pass
E	-115	-52	63	fail
F	-116	-39	77	pass
G	-116	-55	61	fail
H	-114	-42	72	pass
I	-116	-50	66	fail
K	-116	-54	62	fail
L Distance	-117	-34	83	pass
Local	-107	-26	81	pass

IEC 5.5.8 Blocking Test

The IEC requirement for blocking is 90 dBFV (emf), with the unwanted signal at -10 to -1 MHz off-tuned and -1 to 10 MHz off-tuned from the wanted signal that would degrade the SINAD from 20 to 14 dB. This equates to a signal level of -23 dBm at the RF input of the test radio.

Table A-6
Blocking Test Measured Data

radio	I (dBm)				pass/fail
	-10 MHz	-5 MHz	-2 MHz	-1 MHz	
A	-14	-14	-23	-23	pass
B	-19	-20	-29	-29	fail
E	-16	-16	-24	-25	fail
F	-24	-19	-22	-22	fail
G	-18	-19	-26	-28	fail
H	-14	-14	-29	-23	fail
I	-16	-20	-24	-24	fail
K	-16	-17	-26	-26	fail
L Distance Local	-19 -5	-19 -5	-24 -14	-23 -14	fail pass

Table A-7
Blocking Test Measured Data

radio	I (dBm)				pass/fail
	+10 MHz	+5 MHz	+2 MHz	+1 MHz	
A	-19	-21	-24	-24	fail
B	-19	-19	-25	-28	fail
E	-17	-24	-24	-25	fail
F	-15	-15	-22	-22	pass
G	-19	-27	-28	-28	fail
H	-14	-14	-21	-19	pass
I	-18	-20	-24	-24	fail
K	-16	-19	-24	-24	fail
L Distance Local	-16 -4	-17 -4	-24 -12	-24 -14	fail pass