NTIA TR-97-343

Assessment of Compatibility Between 25 and 12.5 kHz Channelized Marine VHF Radios

technical report

U.S. DEPARTMENT OF COMMERCE ● National Telecommunications and Information Administration

NTIA TR 97-343

Assessment of Compatibility Between 25 and 12.5 kHz Channelized Marine VHF Radios

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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.

Additional maritime mobile channels are required to meet the growing demands for the above services in the near future, particularly the demand for digital services. To accommodate the old and new services demand for additional channels, the maritime mobile spectrum needs to be used more efficiently. Narrowbanding of the maritime mobile VHF band from 25 kHz to 12.5 or 6.25 kHz channel bandwidths is one possible solution to make more channels available. However, any technique must take into account factors such as continuing to make low-cost transceivers available to the general boating public and preserving interoperability with existing 25 kHz FM equipment. They must also consider the time period in which these targeted improvements can be achieved. Furthermore, any new technology used to reduce spectrum congestion and improve spectrum efficiency must be able to accommodate existing safety and distress communications.

The United States plans to submit a proposal in the upcoming 1997 World Radio Conference (WRC -97) to permit narrowbanding the maritime mobile VHF band. To support that proposal, the United States Coast Guard and the National Telecommunications and Information Administration (NTIA) conducted bench and radiated tests of 25 kHz (referred to as wideband) and 12.5 kHz (referred to as narrowband) channelized marine radios. Commercial and recreational grade wideband and narrowband radios were tested for susceptibility to intermodulation products and adjacent/interstitial channel interference, and for interoperability. The narrowband radios were prototype commercial grade radios that were not fully optimized for narrowband operation. In addition, a VTS ship transponder receiver (as defined in ITU-R M.825) was tested for susceptibility to adjacent channel interference.

The results of the intermodulation tests showed that commercial grade radios are less susceptible to intermodulation products than the recreational grade radios. The results of the adjacent/interstitial channel interference tests showed that the narrowband radios were less susceptible to adjacent /interstitial interference than the wideband radios, both commercial and recreational grade. The results of the VTS ship transponder tests showed that the transponder receiver performed well in the presence of adjacent channel interference. The results of the interoperability tests showed that the wideband radios are fully interoperable with narrowband radios, with a slight degradation in the operating range of a wideband receiver.

Although the results of the tests showed that the wideband and narrowband radios are interoperable, introducing narrowband radios into the existing 25 kHz environment must be carefully done to minimize the effects of adjacent channel interference on wideband receivers. This is especially true when the narrowband radio is operating on an interstitial channel ±12.5 kHz off-tuned from a regular 25 kHz channel. One method that would help, but not totally eliminate, adjacent channel interference is to ensure geographic separation between adjacently tuned narrowband radio transmitters and wideband receivers. However, this may not be achievable in the entire maritime band due to the fact that most of the frequency channels in the band are not exclusively assigned but shared among a variety of users in the band. Initially, implementing separation distances to allow narrowband operations could be done by those maritime users that have greater control over who uses their services and who can afford narrowband capable equipment.

The range of distances that would be needed for geographic separation for adjacently tuned wideband and narrowband radios were calculated based on data from the bench tests. The results show that for 12.5 kHz of frequency separation from a 25 watt transmitter, the wideband radio required about 12 nmi of separation and the narrowband radio required about 6 nmi of separation to satisfy the test requirements. These results indicate that the narrowband radio was more immune to adjacent channel interference than the wideband radio. The aforementioned separation distances assume minimal degradation in receiver sensitivity for the mobile units. Operational base stations should observe larger separation distances, especially if the working frequencies with mobile units are simplex. Interoperability distances based on data from the bench tests showed that the wideband receiver lost about 3 nmi of operating range when communicating with a narrowband radio, as compared to a wideband radio. The narrowband receiver did not suffer any degradation in operating range when communicating with the wideband transmitter, as compared to communicating with a narrowband transmitter.

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Section One
Introduction

1.1 Background

The maritime mobile frequency band (156-162 MHz) supports maritime communications worldwide. Appendix 18[1] 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.

Although not used extensively, data communications are also available on some channels by arrangement between administrations. Provisions in Appendix 18 consider the use of high-speed data and facsimile transmissions. The Radio Regulations, primarily Articles 59[2] and 60[3], provide technical characteristics for these functions. Most communications in the maritime mobile service utilize analog FM techniques for voice communications, although requirements for digital information exchange are expected to increase in the future.

Public coast station operators have an increased need for additional spectrum with the introduction of semi-automatic and automatic direct dial services in the U.S. Administrations where these services have been introduced have generally seen an increase of 10-20 fold in the amount of ship-to-shore and shore-to-ship traffic. In order to facilitate the proper implementation of automated services, the need for additional operating channels is necessary.

In addition, administrations implementing modern vessel traffic services (VTSs) using such techniques as automated dependent surveillance (ADS) will need internationally compatible radio channels set aside for data transmission. This includes the exchange of traffic and harbor data. VTS systems will take advantage of evolving digital technology moving towards developing a "voiceless" VTS.

To accommodate the maritime mobile service needs for more channels, the maritime mobile band needs to be used more efficiently. Narrowbanding of the maritime mobile VHF band from 25 kHz to 12.5 or 6.25 kHz channel bandwidths is one possible solution to making more channels available to the services described above. However, this technique must take into account factors such as continuing to make low-cost transceivers available to the general boating public and preserving interoperability with existing 25 kHz FM equipment. They must also consider the time period in which these targeted improvements can be achieved.

Furthermore, any new technology used to reduce spectrum congestion and improve spectrum efficiency must be able to accommodate existing safety and distress communications. Channel plans and modulation schemes for both new and existing transceivers must be interoperable and capable of immediately participating in the VHF maritime distress and safety system if narrowbanding is implemented.

The United States will submit a proposal in the upcoming 1997 World Radio Conference (WRC -97) to permit narrowbanding the maritime mobile VHF band. To support that proposal, the United States Coast Guard and the National Telecommunications and Information Administration (NTIA) conducted bench and radiated tests of 25 and 12.5 kHz channelized marine radios. In addition, adjacent channel interference susceptibility tests were performed on a VTS-like transponder system. Reports documenting results of the bench and radiated tests were distributed to the maritime industry for review and comment through the Radio Technical Commission for Maritime Services (RTCM). This report summarizes the objectives, procedures, and results of both the radiated and bench tests.

The VHF radio and transponder bench and radiated test objectives, procedures, and results are discussed in the following sections. Radiated tests were performed in a maritime environment in the South Florida area during August 1996. The bench tests were completed in April 1996 at the ITS laboratory in Boulder, Colorado.

1.2 Test Objectives

The objectives when testing the VHF radios on a bench and in a maritime environment were to: 1) Determine the susceptibility of 12.5 and 25 kHz channelized radios to adjacent/interstitial channel interference, and 2) Evaluate the interoperability of the 12.5 and 25 kHz channelized radios. The bench tests also included testing the 25 and 12.5 kHz radio's susceptibility to intermodulation products. The objective of the intermodulation tests was to evaluate the radios susceptibility to 3rd and 5th order intermodulation products with pairs of frequencies located in the marine band and out-of the marine band. The objective of testing the transponder was to evaluate its performance in the presence of adjacent/interstitial channel interference.

During the radiated tests it was decided to perform additional tests beyond those described in the original test plan circulated through RTCM. The procedures used in those tests and their results are discussed in section 2.1.4 of this report.

1.3 Test Radios

Production radios used for testing were commercially available analog 25 kHz channelized marine FM radios. These 25 kHz radios included three commercial grade radios representative of the type used by commercial boaters and government agencies.

Most recreational boaters use less expensive low-end 25 kHz radios. These types of radios could possibly be more susceptible to interference and interoperability problems and were therefore also tested. NTIA purchased three fixed mount and two hand-held radios of these types from local retailers for testing.

One manufacturer supplied two prototype 12.5 kHz channelized radios for the tests, one was configured as a mobile and the other as a base unit. These radios are not yet commercially available.

The radios are identified by alphabetical code using letters A through K, manufacturers' names and model numbers are not included in this report. These radios are also identified in the bench test report using the same letter. The radio are categorized as either recreational or commercial grade radios and as either fixed-mount or handheld below in table 2-1.

The 25 kHz channelized radios will be referred to as wideband radios and the 12.5 kHz radios will be referred to as narrowband radios for the remainder of this report.

Table 2-1
Radio Description

Radio	Type	Grade
A	fixed-mount 25 kHz	recreational
B	fixed-mount 25 kHz	commercial
C	fixed-mount 25/12.5 kHz	commercial (prototype)
D	fixed-mount 25/12.5 kHz	commercial (prototype)
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
J	fixed-mount 25/12.5 kHz	commercial (prototype)
K	fixed-mount 25 kHz	recreational

The tests were performed according to the radio’s mode of operation (base or mobile) and their channel numbering plan (25 or 12.5 kHz). The proposed channel numbering plan used by the prototype 12.5/25 kHz radios is defined in ITU Study Group 8B document 8B-TEMP/6Rev.1 (Draft Revision of Recommendation ITU-RM.1084[4], “Improved Efficiency in the Use of the Band 156-174 MHz by Stations in the Maritime Mobile Service”). This proposed channel numbering plan was used in this report to denote the channels used for testing.

This recommendation was approved at the international Working Party 8B meeting held in November 1996 and was approved by Study Group 8 in June 1997.

Section Two
Test Results

2.1 Adjacent Signal Susceptibility Tests

The recorded data and test procedures used in the adjacent signal susceptibility bench and radiated tests are described in Appendix A. The following paragraphs summarize the results of the adjacent signal susceptibility tests.

2.1.1 Bench Tests

The results of adjacent signal interference bench tests show that wideband receivers are susceptible to narrowband interferers when the narrowband interferer is off-tuned ±12.5 kHz from the desired signal carrier. However, wideband receivers are less susceptible to narrowband interferers than wideband interferers when the narrowband interferers are off-tuned by at least 25 kHz from the desired signal carrier. For example, receiver A in Table A-1 required an interference power of -59 dBm from a wideband interferer off-tuned 25 kHz to degrade the SINAD from 15 to 12 dB but, as shown in Table A-2, -55 dBm was required for receiver A with a narrowband interferer off-tuned 25 kHz. Receiver A required 4 dB more of interference power from the narrowband interferer than the wideband interferer to degrade the SINAD from 15 to 12 dB. Although this number varies for each radio, it is true in all cases. Clearly, once the narrowband interferer is off-tuned 25 kHz and beyond, the narrow band interferer is less of a concern than the wideband interferer.

These results indicate that narrowband radio transmitters would not adversely affect wideband radio receivers operating 25 kHz and beyond from the narrowband transmitter. However, geographical separation or sharper filtering in the wideband receiver would be necessary if the wideband receiver was operating 12.5 kHz off-tuned from the narrowband transmitter. The cost of additional filtering in the receiver and tighter frequency tolerances should present only a moderate price increase to the overall cost of the radio.

The results of adjacent signal interference tests on narrowband receivers show they are less susceptible to wideband interferers than wideband receivers are to narrowband transmitters. For example, receiver A (a 25 kHz radio) in Table A-2 required an interference power of -97 dBm to degrade the SINAD from 15 to 12 dB when the narrowband interferer was off-tuned -12.5 kHz from the desired signal and -99 dBm for +12.5 kHz off-tuning. The desired signal power for a 15 dB SINAD for receiver A was -114 dBm. The resulting signal-to-interference (S/I) ratios are -17 and -15 dB.

Receiver C (a 12.5 kHz radio) in Table A-7 required an interference power of -86 dBm to degrade the SINAD from 15 to 12 dB for a wideband interferer off-tuned -12.5 kHz and -82 dBm for 12.5 kHz off-tuning. The desired signal power for a 15 dB SINAD for receiver C was -117 dBm. The resulting S/I ratios are -31 dB and -35 dB.

Comparing the S/I ratios of the wideband and narrowband receivers, it can be seen that the narrowband radio (receiver C) has 14 dB better immunity to the wideband interferer than the wideband radio (receiver A) has to the narrowband interferer. Although the S/I ratios are different for each receiver, this is true for all cases of wideband receivers versus the narrowband receiver.

These results indicate that narrowband receivers could operate in a wideband environment as well as wideband radios on 25 kHz channels but would require some geographical separation if they were operating on an interstitial channel 12.5 kHz off-tuned from a regular 25 kHz channel.

The geographical separation distances for adjacently tuned wideband and/or narrowband radios are discussed in section 2.1.3. The distances were calculated using the NTIA NLAMBDA computer propagation model for smooth earth at 50 percent.

2.1.2 Radiated Tests

The results of the adjacent signal interference susceptibility tests show that the narrowband radio was more immune to adjacent channel interference than the wideband radios. The S/I ratio for the narrowband radio was -35 dB whereas the best S/I ratio for the wideband radios (shown in Table A-11) was -10 dB, which was determined for receiver B. Receiver G had the worst S/I of +12. These results were expected and agreed with the results of the bench tests which also showed that the 12.5 kHz receiver with a narrower IF bandwidth is more immune to adjacent channel interference than current wideband radios.

2.1.3 Adjacent Channel Separation Distances

Average channel separation distances for a wideband receiver were calculated based on the separation distances for each wideband receiver. The distances were calculated for a wideband receiver versus adjacently tuned wideband and narrowband transmitters off-tuned by 25 kHz, and for a narrowband transmitter off-tuned by 12.5 kHz. The power of the adjacent transmitters was 25 watts and three cases of antenna heights were considered: 3 meters, 3 and 10 meters, and 10 meters. The distances were calculated based on the data in Tables A-1 and A-2 of Appendix A and the methodology described in Appendix E. The results are shown below in Table 2-1.

Table 2-1
Wideband Receiver Average Adjacent Channel Separation Distances (25w)

Antenna Heights	Δf=25 kHz		Δf=12.5 kHz
	25 watt 25 kHz Transmitter	25 watt 12.5 kHz Transmitter	25 watt 12.5 kHz Transmitter
H1=3 m H2=3 m	1.7 nmi	1.3 nmi	11.9 nmi
H1=3 m H2=10 m	1.9 nmi	1.7 nmi	12.6 nmi
H1=10 m H2=10m.	1.9 nmi	1.7 nmi	13.7 nmi

As shown in column three of Table 2-1, the separation distances for the wideband receivers versus a narrowband transmitter, off-tuned by 25 kHz, are equivalent to the separation distances for a wideband transmitter off-tuned by 25 kHz which are shown in column two. However, the separation distances for the wideband receiver increase when the narrowband transmitter is tuned to the adjacent interstitial channel. The maximum value is 13.7 nautical miles for a transmit and receive antenna height of 10 meters. The variability in the separation distances relative to the average values shown in Table 2-1 for the individual radios was about .4-1 nautical miles for the wideband and narrowband interferers off-tuned by 25 kHz and about 1.7-2.6 nautical miles for the narrowband interferer off-tuned by 12.5 kHz.

Separation distances for a 5 watt transmitter versus a wideband receiver are shown below in Table 2-2.

Table 2-2
Wideband Receiver Average Adjacent Channel Separation Distances (5w)

Antenna Heights	Δf=25 kHz		Δf=12.5 kHz
	5 watt 25 kHz Transmitter	5 watt 12.5 kHz Transmitter	5 watt 12.5 kHz Transmitter
H1=3 m H2=3 m	1.3 nmi	1.3 nmi	8.4 nmi
H1=3 m H2=10 m	1.3 nmi	1.3 nmi	9.0 nmi
H1=10 m H2=10 m	1.3 nmi	1.3 nmi	9.8 nmi

Separation distances for a 1 watt transmitter versus a wideband receiver are shown below in Table 2-3.

Table 2-3
Wideband Receiver Average Adjacent Channel Separation Distances (1w)

Antenna Heights	Δf=25 kHz		Δf=12.5 kHz
	1 watt 25 kHz Transmitter	1 watt 12.5 kHz Transmitter	1 watt 12.5 kHz Transmitter
H1=3 m H2=3 m	.9 nmi	.9 nmi	5.8 nmi
H1=3 m. H2=10 m.	.9 nmi	.9 nmi	6.3 nmi
H1=10 m H2=10 m.	.9 nmi	.9 nmi	6.9 nmi

Table 2-1 represents the situation for a fixed mount transmitter versus a wideband receiver. Tables 2-2 and 2-3 represent the situation for a handheld transmitter versus a wideband receiver. In addition, Tables 2-2 and 2-3 could also represent a wideband receiver versus a fixed transmitter limited to low power operation on certain channels.

Adjacent channel separation distances were also calculated for a narrowband receiver versus a wideband transmitter off-tuned by 12.5 kHz. The power of the adjacent transmitter was 25, 5, and 1 watt. Three cases of antenna heights were considered: 3 meters, 3 and 10 meters, and 10 meters. The distances were calculated based on the data in Table A-7 of Appendix A and the methodology described in Appendix E. The results are shown below in Table 2-4.

Table 2-4
Narrowband Receiver Adjacent Channel Separation Distances

Antenna Heights	Δf=12.5 kHz	Δf=12.5 kHz	Δf=12.5 kHz
	25 watt 25 kHz Transmitter	5 watt 25 kHz Transmitter	1 watt 25 kHz Transmitter
H1=3 m H2=3 m	6.2 nmi	4.3 nmi	3.0 nmi
H1=3 m H2=10 m	6.7 nmi	4.7 nmi	3.5 nmi
H1=10 m H2=10 m	7.1 nmi	5.2 nmi	3.5 nmi

Comparing the entries of column two in Table 2-4 and column four in Table 2-1 it can be seen that the narrowband receiver has a smaller separation distance versus a wideband transmitter off-tuned by 12.5 kHz than vice-versa. For example, the separation distance for the narrowband receiver versus the wideband transmitter for antenna heights of 10 meters is 7.1 nautical miles. However, in the case of the wideband receiver versus the narrowband transmitter off-tuned by 12.5 kHz (using the same antenna heights) the separation distance is 13.7 nautical miles. Clearly the prototype narrowband radio which uses 15 kHz wide IF filters is more immune to adjacent channel interference than current production wideband radios that employ wide band IF's. The narrowband radios could be made even further immune to adjacent channel interference if the IF bandwidths were reduced to 10 kHz.

2.1.4 Additional Radiated Tests

Additional radiated tests were conducted using voice as the modulating signal for both the interferer and desired signal transmitter. These tests were observed by attendees of the RTCM conference. The results of these tests showed that an adjacently tuned interferer modulated by voice could degrade performance of a voice communication link.

The results of the tests using voice-shaped noise versus voice as the modulating signal for the interferer cannot be directly compared. The radiated test with the voice-shaped noise as the interfering signal modulation used a 1 kHz tone to modulate the desired signal radio to conduct a SINAD test. The SINAD test is a quantitative test that has a set goal for its results, which in our tests was 15 dB without interference to 12 dB with interference. The radiated test with voice as the modulating signal for the interferer and the desired signal transmitter was a qualitative test with no direct measurement of voice or message intelligibility attempted.

The goal of the quantitative test was to introduce interference into the communication link which would lower the SINAD. Lowering of the SINAD indicates that the performance of the communication link has suffered some degradation. This was done by placing the vehicle containing the interferer radio at a specific geographical location. With the interference being put into the link, the 1 kHz tone could still be heard from the receiver being tested, along with noise in the background. The background noise was due to the interferer being modulated by the VSN. When the qualitative test was done with the interferer staying at that same location but using voice as a modulator, one would expect to hear voice as the background interference.

2.2 Interoperability Tests

The recorded data and test procedures used in the interoperability bench and radiated tests are described in Appendix B. The following paragraphs summarize the results of the interoperability tests.

2.2.1 Bench Tests

The results of the interoperability tests of a narrowband transmitter and wideband receivers varied from radio to radio. Radio F in Table B-1 required -116 dBm of power from a narrowband transmitter to produce a 15 dB SINAD and -116 dBm of power from a wideband transmitter. However, radio G required -110 dBm of power from a narrowband transmitter and -115 dBm of power from a wideband transmitter to produce a 15 dB SINAD in the receiver, a difference of 5 dB. The other radios in Table B-1 required more power from the narrowband transmitter than the wideband transmitter to produce the 15 dB SINAD.

In a marine environment, these differences in wideband receiver sensitivity to 25 and 12.5 kHz transmitters would equate to some wideband radios having a reduced operating range when communicating with narrowband radios. Some of this is due to the narrowband transmitter having a 2 kHz signal deviation while the wideband transmitter was set to a 3 kHz signal deviation. With a lesser signal deviation, the narrowband signal contained less energy for the wideband receiver to demodulate.

The results of the interoperability tests of a narrowband receiver with a wideband transmitter in Table B-2 showed that the narrowband radio receiver required -117 dBm from a narrowband transmitter and -119 dBm from a wideband transmitter to produce a 15 dB SINAD. Therefore, properly designed narrowband radio receivers should be compatible with wideband transmitters with little loss of operating range.

2.2.2 Radiated Tests

The results of the interoperability tests listed in Table 5-3 showed that the wideband receivers were compatible with the narrowband transmitter. The difference for the received desired signal power from the narrowband and wideband transmitters at the input to the radio being tested to achieve a 15 dB SINAD varied from 2 to 10 dB.

2.2.3 Interoperability Distances

Average interoperability distances for a wideband receiver (e.g., the distance at which a 15 dB SINAD can be attained) were calculated based on the interoperability distances for each wideband receiver. The distances were calculated for a wideband receiver communicating with wideband and narrowband radios transmitting at powers of 25, 5, and 1 watt for three cases of antenna heights: 3 meters, 3 and 10 meters, and 10 meters. The distances were calculated based on the desired signal powers contained in columns two and three of Table B-1 in Appendix B and the methodology described in Appendix E. The average interoperability distances, in nautical miles, for the wideband receivers communicating with wideband and narrowband transmitters are shown below in Table 2-5.

Table 2-5
Wideband Receiver Average Interoperability Distances

	Pt = 25 Watts		Pt= 5 Watts		Pt=1 Watt	
Antenna Heights	25 kHz Transmitter	12.5 kHz Transmitter	25 kHz Transmitter	12.5 kHz Transmitter	25 kHz Transmitter	12.5 kHz Transmitter
H1= 3 m H2= 3 m	26 nmi	23 nmi	20 nmi	18 nmi	15 nmi	13 nmi
H1= 3 m H2= 10 m	28 nmi	25 nmi	21 nmi	19 nmi	16 nmi	14 nmi
H1= 10 m H2= 10 m	29 nmi	26 nmi	23 nmi	20 nmi	17 nmi	15 nmi

As shown in columns two through six of Table 2-5, the wideband receiver will have a minimal loss of operating range when communicating with a narrowband transmitter, as compared to a wideband transmitter operating at the same power output and antenna heights. On average, the wideband receiver will only experience 2 to 3 nautical miles of degradation in operating range when communicating with the narrowband transmitter. The variability in the interoperability distances for the individual wideband radios relative to the averages shown in Table 2-5 was about 3.5 nautical miles for the wideband transmitter and about 3.5 miles for the narrowband transmitter.

Interoperability distances were also calculated for a narrowband receiver communicating with a wideband and a narrowband radio transmitting at powers of 25, 5, and 1 watt. Three antenna heights were considered: 3 meters, 3 and 10 meters, and 10 meters. The distances were calculated based on the desired signal powers contained in columns two and three of Table B-2 in Appendix B and the methodology described in Appendix E. The average interoperability distances, in nautical miles, for the narrowband receiver communicating with wideband and narrowband transmitters are shown below in Table 2-6.

Table 2-6
Narrowband Receiver Interoperability Distances

	Pt = 25 Watts		Pt= 5 Watts		Pt=1 Watt	
Antenna Heights	25 kHz Transmitter	12.5 kHz Transmitter	25 kHz Transmitter	12.5 kHz Transmitter	25 kHz Transmitter	12.5 kHz Transmitter
H1= 3 m H2= 3 m	29 nmi	27 nmi	23 nmi	21 nmi	17 nmi	15 nmi
H1= 3 m H2= 10 m	30 nmi	29 nmi	24 nmi	22 nmi	18 nmi	16 nmi
H1= 10 m H2= 10 m	32 nmi	30 nmi	25 nmi	23 nmi	19 nmi	17 nmi

As shown in columns two through six of Table 2-6, the narrowband receiver will not experience any loss of operating range when communicating with a wideband transmitter, as compared to a narrowband transmitter operating at the same output power and antenna heights.

These interoperability distances show that wideband receivers should be compatible with narrowband transmitters and vice-versa, with minimal effect on the operating range of either type of radio.

2.3 Intermodulation Susceptibility Tests

The recorded data and the procedures used to perform the intermodulation susceptibility tests are described in Appendix C. The following paragraphs summarize the results of the tests.

The results of the 3rd order intermodulation susceptibility tests with wideband receivers showed a wide range of intermodulation rejection (IMR) values between manufacturers and price range of radios. In addition, the IMR for each radio varied if the pairs of signals generating the intermodulation products were in the receiver’s RF pass band, or out-of the receiver’s RF pass band. For example, in Table C-1 receiver A (a recreational grade wideband radio) had an in-band IMR of -63 dB and from Table C-2 an out-of-band IMR of -68 dB. Receiver B, a commercial grade wideband radio, had an in-band IMR of -81 dB but saturated before a measurement could be made on the out-of-band IMR.

The results of these tests indicate that front-end filtering in the radios lessen their susceptibility to out-of-band signals that cause the intermodulation products in the radio receiver. Radio A’s out-of-band response was 5 dB better than its in-band response. The amount of additional IMR rejection for the out-of-band signal pairs is dependent on the radio being tested.

A more important result is the difference between commercial grade and recreational grade radios for the in-band IMR response. In this case the difference between receivers A and B is 18 dB. In a maritime situation, this difference in IMR performance would translate into radio B having a greater operational range than radio A, when a paging transmitter (158.700 MHz) and a rail/dock transmitter (161.025 MHz) were active in the area. Although the IMR varied from radio to radio, the commercial grade radios always had a better IMR than the recreational grade radios in these tests.

The results of the 5th order intermodulation susceptibility tests with wideband receivers (shown in Tables C-3 and C-4) revealed that most radios, both commercial and recreational grade, saturated before the intermodulation effects could be generated and verified. This was true for the in-band and out-of-band signal pairs response. However, when a 5th order IMR was measured its value was better than the 3rd order IMR response. For example, radio A's 5th order IMR was 10 dB better than its 3rd order IMR for both the in-band and out-of-band signal pairs.

The results of the 3rd order intermodulation susceptibility tests with narrowband receivers (radio C in Tables C-1 and C-2) showed that it had a better in-band and out-of-band IMR than the recreational grade 25 kHz radios. As in the case of the 25 kHz radios, the out-of-band IMR was greater then the in-band IMR. The in-band IMR was measured to be -77 dB and the out-of-band IMR was -84 dB. These IMR's were on par with the commercial grade wideband radios. This result was not unexpected because the radio was a prototype of a commercial grade narrowband radio. The manufacturer claims that production narrowband radios will come close to a -90 dB IMR.

Recreational grade narrowband radios were not available for this test, but should be tested if they go into production. Currently, the FCC does not mandate IMR performance standards for marine VHF radios sold in the United States. Many European nations require that marine radios sold in their country adhere to the International Electrotechnical Commission (IEC) IMR specification of -68 dB[5]. This level was easily met by commercial grade radios in the tests but could be a problem for recreational grade radios.

2.4 VTS-Like Transponder Tests

The recorded data and the procedures used to perform the transponder tests are described in Appendix D. The following paragraphs summarize the results of the tests.

The results of the adjacent signal interference susceptibility tests on the transponder showed that the dominant interference mechanism was front end saturation of the transponder receiver. Receiver saturation generally occurs at high interference power levels which equates to a higher degree of immunity to interference.

These test results show that, with a strong desired signal, this particular VTS-like transponder receiver was able to operate within the system with a high degree of immunity to adjacent signal interference.

2.4.1 VTS-Like Transponder Adjacent Channel Separation Distances

The VTS-like transponder receiver operating on an interstitial channel would require less than one quarter of a nautical mile of separation from a transmitter operating on the adjacent regular marine channel (12.5 kHz of frequency separation). This assumes the VTS-like transponder receiver has a strong desired signal (-60 dBm) and the interferer radio is transmitting with an output power of 25 watts.

Section Three
Conclusions

3. Conclusions

From reviewing the results of the bench and radiated tests, it should be possible to introduce radios and/or VTS like systems on 12.5 kHz channels provided that proper frequency management techniques such as geographical separation and/or receiver standards are implemented. A further discussion of each topic is given in the following paragraphs.

Geographical separation is an option that accommodates narrowband operations for specific licensed and/or assigned marine VHF operations, such as public coast stations and government operations. Public coast stations are licensed by the FCC and protected to a 17 dBuV contour to prevent interference from occurring between competitors on adjacent sites/channels. Public coast station operators that have licenses on adjacent VHF channels in the same area could use the interstitial between them as data or communication channels. In cases where multiple coast station licensees operate in the same area, the interstitial channels could still be used as long as coordination is performed between the interested parties.

Government radio communications operations in certain frequency bands are internally coordinated and licensed, therefore implementation of 12.5 kHz channels by government users can be conducted by using proper frequency management techniques such as geographic separations and/or exclusive use of 12.5 kHz equipment. This situation is similar to the land mobile implementation of interstitial 12.5 kHz channels into the existing 25 kHz environment in the 162-174 MHz and 406-420 MHz frequency bands.

Separation distances based on bench test results show that to achieve electromagnetic compatibility with geographic separation, wideband radios with wide IF receivers would require about 11-13 nautical miles of separation from radios operating on adjacent narrowband channels. The receivers of the prototype narrowband radios with narrower IF bandwidths are more resistant to interference. These types of receivers would require about 6-7 nautical miles of geographic separation. These distances are based on a transmit power of 25 watts and would be smaller if the power was reduced. The receivers of the VTS-like transponders are even more resistant to interference and would require less than a quarter mile of geographic separation to achieve electromagnetic compatibility.

Receiver standards are another option that could help implement narrowband operations in the marine VHF band. Current wideband marine radios used in the tests employ IF bandwidths as wide as the channel spacing of 25 kHz. The prototype narrowband radios used in the tests were designed with 15 kHz wide IF's to be compatible with both wide band and narrowband operations. They were found to be less susceptible to adjacent channel interference than the current wideband designs that use wide IF filters. Future 25/12.5 kHz radios could be designed with narrower IF's for better performance in the presence of interference without sacrificing receiver sensitivity or range.

In addition, the manufacturer of the prototype narrowband radios has suggested that separate IF filters could be used on narrowband channels. The channel space of a narrowband channel is 12.5 kHz. The IF filter does not need to be as wide as the channel spacing and could be reduced to approximately 10 kHz. This would further reduce its susceptibility to adjacent channel interference.

Receiver intermodulation rejection standards could also be used by manufacturers as guidelines when developing future marine VHF radios.

References

1. International Telecommunication Union (ITU) Radio Regulations. Appendix 18, *Table of Transmitting Frequencies in the Band 156-174 MHz for Stations in the Maritime Mobile Service*, 1994.

2. International Telecommunication Union (ITU) Radio Regulations. Article 59, *Conditions to be Observed in the Maritime Mobile Service and in the Maritime Mobile-Satellite Service,* 1994.

3.International Telecommunication Union (ITU) Radio Regulations. Article 60, *Special Rules to the Use of Frequencies in the Maritime Mobile Service,* 1994.

4. International Telecommunication Union (ITU) Recommendation ITU-RM 1084, *Improved Efficiency in the use of the band 156-174 MHz by Stations in the Maritime Mobile Service*, 1994.

5. International Electrotechnical Commission (IEC) draft IEC 1097-7, *Global Maritime and Distress and Safety System (GMDSS) Part 7: Shipborne VHF Radiotelephone Transmitter and Receiver- Operational and Performance Requirements, Methods of Testing and Required Test Results*, 1997.

Appendix A
Adjacent Channel Test Procedures and Recorded Data

Adjacent Channel Bench Tests

The marine VHF radios (both 25 and 12.5 kHz channelized units) were tested for susceptibility to adjacent channel interference by using either 25 or 12.5 kHz channelized marine radios as interfering transmitters. A diagram of the test set-up used to test the 25 kHz radios is shown below in Figure A-1. The frequencies selected for the desired signal channel and interferer radio for the tests are described in Appendix F.

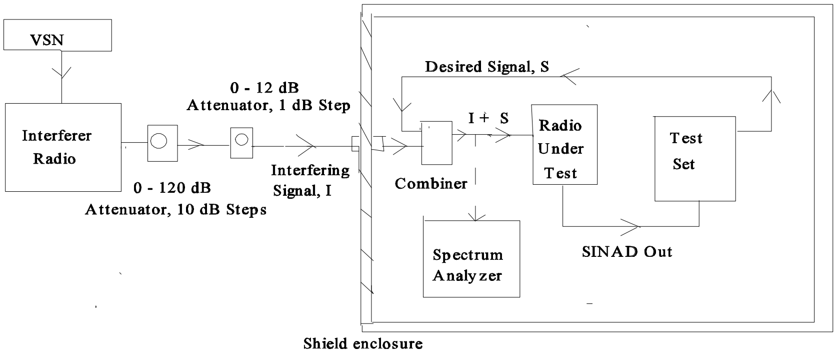

Figure A-1
25 kHz Receiver Bench Test Set-up

The following steps were taken to perform the tests on the 25 kHz radio receivers:

1. The receiver of the 25 kHz radio under test was tuned to the desired marine channel. The test set which was used as the 25 kHz desired signal transmitter was also tuned to that same channel and was modulated by an internal 1 kHz tone adjusted in amplitude for a 3 kHz signal deviation.

2. The power of the desired signal, S, from the RF output of the test set was adjusted and its value recorded in dBm when the SINAD of the radio receiver under test was 15 dB.

3. The interferer radio was set to the proper adjacent frequency. The frequencies used by the interferer radio and the desired signal radio for the testing are described in Appendix A.

4. The interferer radios were modulated by voice-shaped noise (VSN) played from a tape in a cassette player. The peak amplitude of the VSN signal from the cassette tape was matched as closely as possible

to the amplitude of a 1 kHz tone that would produce a 2.5 kHz signal deviation for a 25 kHz interferer radio. For the 12.5 kHz interferer, the peak amplitude of the VSN signal from the cassette tape was matched as closely as possible to the amplitude of a 1 kHz tone that would produce a 1.5 kHz signal deviation.

5. The RF output of the interferer radio, I, was fed through the step attenuators and then through the shielded enclosure. This signal was then combined with the desired signal, S, from the test set and connected to the RF input of the radio being tested.

6. The interferer radio was keyed so that it would transmit. The step attenuators were set to their maximum values and then adjusted till the interference power reduced the SINAD of the radio being tested from 15 to 12 dB.

7. The combiner at the RF input to the radio being tested was then connected to the spectrum analyzer and the RF power of the interfering signal, I, was measured in dBm. In some instances, the power of the interferer was below the noise floor of the spectrum analyzer. For those cases a 20 dB RF amplifier was connected to the output of the combiner before the measurement was made.

8. The interferer radio was tuned to the next adjacent frequency from the desired channel and the above steps were repeated till all adjacent frequencies were tested for that particular radio under test.

For testing 12.5 kHz radio receivers, the test set was used as the interferer radio and the 12.5 kHz radio located outside the shield room functioned as the desired signal radio. In this case, the desired signal radio was externally modulated by a 1 kHz tone for a 2.0 kHz signal deviation and its RF power adjusted by the step attenuators. The RF power of the test set acting as the 25 kHz interferer was adjusted from a front panel control and externally modulated by the VSN played from the cassette player. The peak amplitude of the VSN signal from the cassette tape was matched as closely as possible to the amplitude of a 1 kHz tone that would produce a 2.5 kHz signal deviation from the test set acting as the interferer radio. The test procedures were then repeated for the 12.5 kHz radio tests as in the 25 kHz radio tests, which was to reduce the SINAD of the 12.5 kHz radio receiver from 15 to 12 dB.

A diagram of this test set-up is shown below in Figure A-2. The frequencies used during these tests are described in section Appendix F.

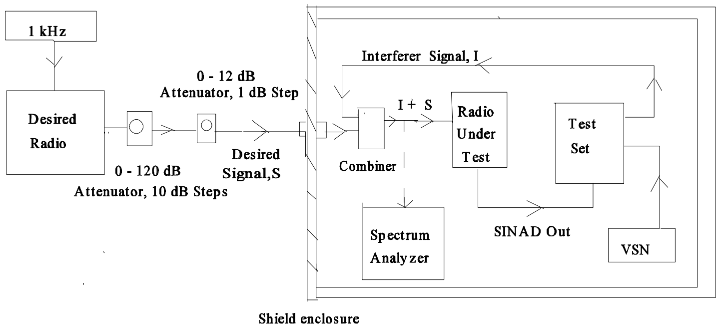

Figure A-2
12.5 kHz Receiver Test Set-up

Adjacent Signal Bench Test Results

The results of the adjacent interference susceptibility tests are contained in the following tables. Each table lists the desired signal power of each radio along with the power of the adjacent interferer needed to reduce the SINAD of the radio being tested from 15 to 12 dB (for each adjacent interference frequency).

Table A-1 contains the results of 25 kHz radio receivers versus a 25 kHz interferer on a simplex channel.

Table A-1
25 kHz receiver vs. 25 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)			
		-50 kHz	-25 kHz	25 kHz	50 kHz
Receiver A	-114	-48	-59	-58	-50
Receiver B	-119	-53	-63	-61	-51
Receiver E	-115	-48	-58	-59	-48
Receiver F	-116	-48	-58	-59	-48
Receiver G	-115	-55	-64	-62	-53
Receiver H	-115	-49	-61	-58	-47
Receiver I	-117	-51	-61	-60	-51
Receiver K	-118	-51	-60	-60	-51

Table A-2 contains the results of 25 kHz radio receivers versus a 12.5 kHz interferer on a simplex channel.

Table A-2
25 kHz receiver vs. 12.5 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)							
		-50.0 kHz	-37.5 kHz	-25.0 kHz	-12.5 kHz	12.5 kHz	25.0 kHz	37.5 kHz	50.0 kHz
Receiver A	-114	-46	-51	-55	-97	-99	-54	-54	-51
Receiver B	-119	-53	-55	-59	-99	-90	-59	-53	-52
Receiver E	-115	-48	-51	-56	-92	-95	-56	-52	-49
Receiver F	-116	-48	-50	-55	-95	-95	-55	-50	-48
Receiver G	-115	-55	-58	-63	-101	-99	-60	-59	-55
Receiver H	-115	-49	-55	-55	-103	-92	-54	-51	-49
Receiver I	-117	-50	-53	-57	-97	-101	-56	-52	-50
Receiver K	-118	-49	-52	-55	-105	-71	-54	-50	-48

Table A-3 contains the results of 25 kHz radio receivers versus a 25 kHz interferer on a duplex channel testing the mobile receiver.

Table A-3
25 kHz receiver vs. 25 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)			
		-50 kHz	-25 kHz	25 kHz	50 kHz
Receiver A	-114	-51	-60	-61	*
Receiver E	-115	-48	-58	-60	*

Table A-4 contains the results of 25 kHz radio receivers versus a 12.5 kHz interferer on a duplex channel testing the mobile receiver.

Table A-4
25 kHz receiver vs. 12.5 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)							
		-50.0 kHz	-37.5 kHz	-25.0 kHz	-12.5 kHz	12.5 kHz	25.0 kHz	37.5 kHz	50.0 kHz
Receiver A	-114	-46	-49	-54	-129	-113	-56	-53	*
Receiver E	-115	-42	-48	-52	-110	-115	-54	-50	*

Duplex communications requires that one radio be configured as a base unit and the other as a mobile. Most recreational boaters do not use base station radios in regular operations on duplex channels. For the most part base station marine radios on duplex channels in the United States are only used by those selling public correspondence services from coast stations to commercial shipping operators.

Table A-5 contains the results of a 25 kHz radio receiver versus a 25 kHz interferer on a duplex channel testing the base receiver.

Table A-5
25 kHz receiver vs. 25 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)			
		-50 kHz	-25 kHz	25 kHz	50 kHz
Receiver D	-119	-51	-59	-58	-51

Table A-6 contains the results of a 25 kHz radio receiver versus a 12.5 kHz interferer on a duplex channel testing the base receiver.

Table A-6
25 kHz receiver vs. 12.5 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)							
		-50.0 kHz	-37.5 kHz	-25.0 kHz	-12.5 kHz	12.5 kHz	25.0 kHz	37.5 kHz	50.0 kHz
Receiver D	-119	-56	-58	-61	-96	-88	-61	-56	-54

The 12.5 kHz channelized radios were tested for susceptibility to interference from a 25 kHz interferer. The results of adjacent signal interference tests for the 12.5 kHz mobile unit on a simplex channel versus a 25 kHz interferer are contained in Table A-7.

Table A-7
12.5 kHz Receiver vs. 25 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)			
		-37.5 kHz	-12.5 kHz	12.5 kHz	37.5 kHz
Receiver C	-117	-65	-86	-82	-64

The results of adjacent signal interference tests for the 12.5 kHz mobile unit on a duplex channel versus a 25 kHz interferer are contained in Table A-8.

Table A-8
12.5 kHz Receiver vs. 25 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)			
		-37.5 kHz	-12.5 kHz	12.5 kHz	37.5 kHz
Receiver C	-117	-78	-89	-82	-73

The results of adjacent signal interference tests for the 12.5 kHz base unit on a duplex channel versus a 25 kHz interferer are contained in Table A-9.

Table A-9
12.5 kHz Receiver vs. 25 kHz Transmitter

Radio under test	Desired Signal Power (dBm)	Power of Adjacent Interferer (dBm)			
		-37.5 kHz	-12.5 kHz	12.5 kHz	37.5 kHz
Receiver J	-114	-58	-67	-65	-60

Adjacent Channel Radiated Tests

The marine VHF radios (both 25 and 12.5 kHz channelized units) were tested for susceptibility to adjacent channel interference for the radiated tests by using either 25 or 12.5 kHz channelized marine radios as interfering transmitters. The frequencies of the channels used in these tests are shown in Table A-2 of Appendix A.

A diagram of the test set-up used to test the 25 kHz radios is shown below in Figure A-3.

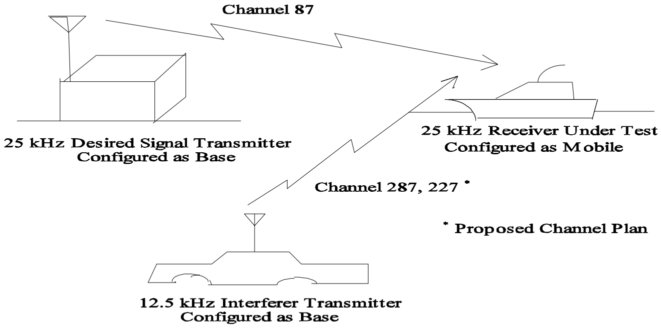

Figure A-3
25 kHz Receiver Radiated Test Set-up

The following steps were taken to perform the interference susceptibility tests on the 25 kHz radio receivers:

1. The receiver of the 25 kHz radio (configured as a mobile) being tested on board the boat was tuned to marine channel 87 and connected to a whip antenna. The 25 kHz desired signal transmitter (configured as a base) was also tuned to channel 87 and modulated by an 1 kHz tone adjusted in amplitude for a 3 kHz signal deviation. The RF output of the desired signal transmitter was connected to an antenna located on the roof of Ross Engineering.

2. The desired signal transmitter at the test facility was keyed. The boat moved out from the dock (located approximately 4.5 nautical miles from the test facility) into Clearwater Harbor and stopped when the SINAD of the radio being tested measured 15 dB with the communications test set. At that location, the level of the desired signal power was measured (at the receiver input) in dBm with the spectrum analyzer and its value recorded. The location of the boat was determined in latitude and longitude with a GPS receiver.

3. The 12.5 kHz interferer radio (configured as a base) was located in a car on the boat dock (approximately 2 miles from the boat) and was tuned to either adjacent interstitial channel 287 or 227. The carrier of these channels are +12.5 and -12.5 kHz from the carrier of channel 87. The RF output of the radio was connected to a 3 dB attenuator and then into adjustable RF step attenuators. The output of the adjustable attenuators was then connected to a whip antenna mounted on the roof of the car.

4. The interferer radio was modulated by voice-shaped noise (VSN) played from a tape in a cassette player. The peak amplitude of the VSN signal from the cassette tape was matched as closely as possible to the amplitude of a 1 kHz tone that would produce a 1.5 kHz signal deviation.

5. The interferer radio was keyed so that it would transmit on either adjacent interstitial channel. The RF power output of the interferer radio (located in the car) was adjusted with the step attenuators until the SINAD of the 25 kHz radio being tested (located in the boat) measured 12 dB with the test set. The location of the car was determined in latitude and longitude with a GPS receiver.

6. The cable to the RF input to the radio being tested on-board the boat was then connected to the spectrum analyzer, and the received RF power of the interferer radio was measured in dBm with the spectrum analyzer and its value recorded.

7. Steps one through six were repeated for each 25 kHz radio being tested.

A diagram of the test set-up used to test the 12.5 kHz radio's susceptibility to an adjacently tuned 25 kHz transmitter is shown below in Figure A-4.

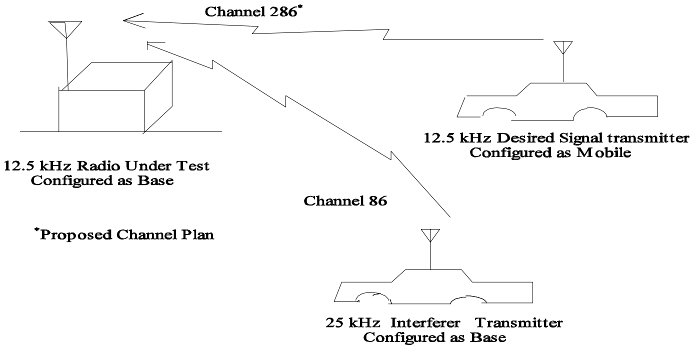

Figure A-4
12.5 kHz Receiver Radiated Test Set-up

The following steps were taken to perform the interference susceptibility tests on the 12.5 kHz radio receiver:

1. The receiver of the 12.5 kHz radio (configured as a base) being tested was located at a test facility in Tampa and was tuned to marine channel 286. The RF input to the radio was connected to adjustable RF attenuators and then to an antenna mounted on the roof the building. The 12.5 kHz desired signal transmitter (configured as a mobile) was also tuned to channel 286 and modulated by an 1 kHz tone adjusted in amplitude for a 2 kHz signal deviation. The RF output of the desired signal transmitter was connected to a whip antenna mounted on the roof of the car.

2. The desired signal transmitter in the car was keyed up and moved to a point approximately 1 mile north of test facility and stopped. The received desired signal power in the lab was adjusted with the attenuators until the test set measured a 15 dB SINAD for the 12.5 kHz radio being tested. The level of the desired signal power at the receiver input was then measured in dBm with the spectrum analyzer and its value recorded. The location of the car containing the desired signal transmitter was determined in latitude and longitude with a GPS receiver.

3. The 25 kHz interferer radio (configured as a mobile) was located in another car and was tuned to channel 86. The interferer radio was modulated by voice-shaped noise (VSN) played from a tape in a cassette player. The peak amplitude of the VSN signal from the cassette tape was matched as closely as possible to the amplitude of a 1 kHz tone that would produce a 2.5 kHz signal deviation.

4.The RF output of the 25 kHz interferer radio was connected to a 3 dB attenuator and then into adjustable RF attenuators. The output of the adjustable attenuators was then connected to a whip antenna mounted on the roof of the car.

5. The interferer radio was keyed so that it would transmit on channel 86. The car then moved south of the test facility and stopped when the SINAD of the 12.5 kHz radio being tested measured 12 dB with the communications test set. The location of the car containing the interferer transmitter was determined in latitude and longitude with a GPS receiver.

6. The received power of the 25 kHz interferer radio at the input to the 12.5 kHz radio (located at the test facility) was then measured in dBm with the spectrum analyzer and its value recorded.

7. As an additional test, the car containing the interferer radio moved closer to the test facility and stopped when the SINAD of the radio being measured in the lab was further reduced by 2-3 dB and the 1 kHz tone could no longer be heard.

8. The received power of the interferer radio at the input to the 12.5 kHz radio being tested was then measured in dBm with the spectrum analyzer and its value recorded. The GPS position of the car containing the interferer radio was also determined.

Adjacent Channel Radiated Test Data

The results of the adjacent signal interference susceptibility tests on the 25 kHz receivers are contained in the following paragraphs.

Column one in Table A-10 lists the radio receiver being tested. Column two lists the desired signal power required by each 25 kHz radio to produce a 15 dB SINAD as measured with the communications test set. Column three lists the received signal power of the adjacent narrowband transmitter at the receiver input which reduced SINAD of the 25 kHz radio receiver from 15 to 12 dB. The narrowband transmitter was operating on channel 227 which is -12.5 kHz off-tuned from the desired signal carrier of channel 87. Column four lists the received signal power of the narrowband transmitter at the receiver input which reduced the SINAD from 15 to 12 dB. In this case the interferer transmitter was operating on channel 287, which is 12.5 kHz off-tuned from channel 87.

Table A-10
25 kHz Receiver Radiated Test Data Vs 12.5 kHz Transmitter

25 kHz Radio	**Desired Signal Power,S (dBm)**	**Interferer power, I (dBm)**	
		-12.5 kHz off-tuned Channel 227	**12.5 kHz off-tuned Channel 287**
Receiver A	-107	-100	-109
Receiver B	-126	-116	-116
Receiver E	-108	-94	-112
Receiver F	-105	-95	-106
Receiver G	-111	-112	-123
Receiver H	-113	-114	-115
Receiver I	-124	-114	-120
Receiver K	-112	-107	-109

The signal-to-interference ratio (S/I) in dB for each radio was calculated by subtracting the interference power, I, from the desired signal power S. The results are shown below in Table A-11.

Table A-11
25 kHz Receiver S/I Values

25 kHz Radio	**Signal-to-Interference, S/I (dBm)**	
	-12.5 kHz off-tuned Channel 227	**12.5 kHz off-tuned Channel 287**
Receiver A	-7	2
Receiver B	-10	-10
Receiver E	-14	4
Receiver F	-10	1
Receiver G	1	12
Receiver H	1	2
Receiver I	-10	4
Receiver K	-5	-3

The location of the desired 25 kHz signal transmitter, the 12.5 kHz interferer transmitter, and the 25 kHz the radio for these tests are shown below in Table A-12.

Table A-12
25 kHz Receiver Test Locations

	Latitude	Longitude
Desired Transmitter	27E 53.147' N	82E 45.679' W
Interferer Transmitter	25E 55.066' N	82E 49.950' W
Radio under test	27E 56.597' N	82E 49.520' W

The results of the adjacent signal interference susceptibility tests on the 12.5 kHz receiver are contained in the following paragraphs.

The desired signal transmitter and the radio being tested were operating on duplex channel 286. The desired signal transmitter was configured as a mobile and the radio being tested was configured as a base. The 12.5 kHz receiver required a desired signal power, S, of -117 dBm from a 12.5 kHz transmitter to produce a 15 dB SINAD as measured with the communications test set without interference present in the link.

The 25 kHz interferer was operating on duplex channel 86 and configured as a mobile. It was 12.5 kHz off-tuned from the 12.5 kHz desired signal carrier. The SINAD of the radio being tested was reduced from 15 dB to 12 dB when the interferer power, I, at the input to the radio was -82 dBm. The resulting signal-to-interference ratio (S/I) is -35 dB. Due to frequency licensing restrictions the 12.5 kHz radio was not tested with a 25 kHz interferer off-tuned by -12.5 kHz.

The locations of the desired 12.5 kHz signal transmitter, the 25 kHz interferer transmitter, and the 12.5 kHz radio for these tests are shown below in Table A-13.

Table A-13
12.5 kHz Receiver Test Locations

	Latitude	Longitude
Desired Transmitter	27E 54.120' N	82E 45.720' W
Interferer Transmitter	27E 52.794' N	82E 45.701' W
Radio under test	27E 53.147' N	82E 45.679' W

In the second part of this test, the interferer moved closer to the radio under test and stopped when the 1 kHz desired signal tone was unintelligible. At this point, the power of the interferer at the input to the radio under test was measured to be -78 dBm. The location of the interferer was 27E 53.447' N latitude and 82E 45.731' W longitude.

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Appendix B
Interoperability Test Procedures and Recorded Data

Bench Tests Procedures

The interoperability of 25 and 12.5 kHz channelized marine VHF radios was bench tested by measuring the sensitivity of 25 kHz receivers with a 12.5 transmitter and the sensitivity of 12.5 kHz receivers with a 25 kHz transmitter. The sensitivity of 25 kHz receivers to a 12.5 kHz transmitter was performed using the test set-up below in Figure B-1. The frequencies selected for these tests are described in Appendix F.

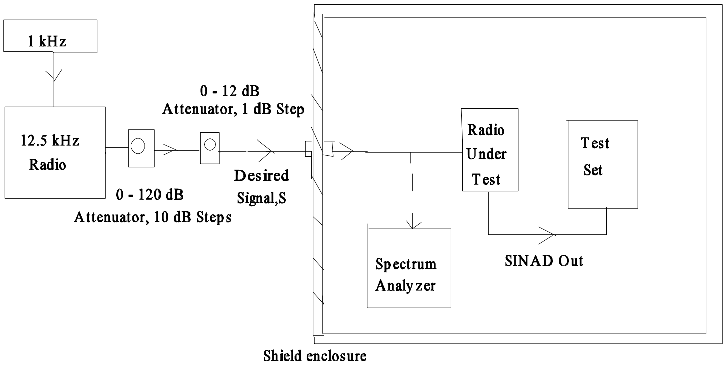

Figure B-1
25 kHz Receiver Interoperability Bench Test Set-up

The following steps were taken to perform the tests on the 25 kHz radio receivers:

1. The 12.5 kHz radio was set to the same channel as the 25 kHz radio being tested.

2. The 12.5 kHz radio was modulated by a 1 kHz tone adjusted in amplitude to produce a 2 kHz signal deviation.

3. The RF output of the 12.5 kHz radio, S, was fed through the step attenuators and then through the shielded enclosure. This signal was then connected to the RF input of the 25 kHz radio being tested.

4. The 12.5 kHz radio was keyed so that it would transmit. The step attenuators were set to their maximum values and then adjusted till the output power of the 12.5 kHz radio produced a 15 dB SINAD for the 25 kHz radio being tested.

5. The power of the desired signal, S, was measured in dBm with the spectrum analyzer and its value recorded.

For testing the interoperability of 12.5 kHz radio receivers with 25 kHz transmitters, the test set was used as the desired signal transmitter. The amplitude of the internal 1 kHz tone generator in the test set was set to a value that would produce a 3 kHz signal deviation. The RF power output of the test set was connected to the RF input of the 12.5 kHz radio and its level adjusted through a front panel control. The RF power of the test set was increased from -139 dBm to a value that would produce a 15 dB SINAD on the 12.5 kHz radio. A diagram of this test set-up is shown below in Figure B-2.

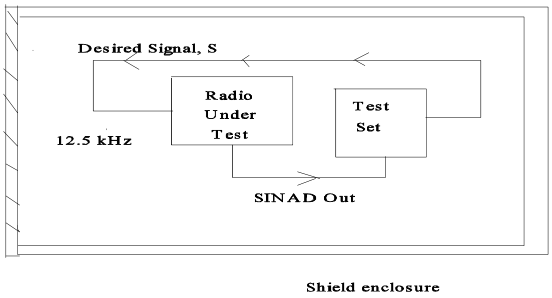

Figure B-2
12.5 kHz Receiver Interoperability Bench Test Set-up

The value of the RF power of the test set was recorded from the front panel in dBm when the SINAD measured 15 dB.

Bench Test Results

The results of the bench interoperability tests between a 12.5 kHz transmitter and the 25 kHz receivers are contained in the following paragraphs.

Simplex marine channel 22A was used as the desired signal channel for testing the interoperability of a 12.5 kHz transmitter with 25 kHz receivers. Column one in Table B-1 lists the receiver model and column two lists the amount of power in dBm for the 12.5 kHz transmitter to produce a 15 dB SINAD in the 25 kHz receiver. Column three lists the desired signal power in dBm from a 25 kHz transmitter required to produce the 15 dB SINAD.

Table B-1
25 kHz Receivers Interoperability Bench Data

Receiver	12.5 kHz Desired Signal, S (dBm)	25 kHz Desired Signal, S (dBm)
Receiver A	-111	-114
Receiver B	-117	-119
Receiver E	-114	-115
Receiver F	-116	-116
Receiver G	-110	-115
Receiver H	-111	-115
Receiver I	-113	-117
Receiver K	-118	-118

The results of the bench interoperability tests between a 25 kHz transmitter and the 12.5 kHz receivers are contained in the following paragraphs.

Simplex marine channel 22A and duplex marine channel 85 were used as the desired signal channels for testing the interoperability of a 12.5 kHz receiver with a 25 kHz transmitter. Column one in Table B-2 contains the receiver type or category and column two lists the amount of power in dBm required for the 25 kHz transmitter to produce a 15 dB SINAD in the 12.5 kHz receiver. Column three lists the desired signal power in dBm from a 12.5 kHz transmitter required to produce the 15 dB SINAD. Radio C was used as the 12.5 kHz receiver in both cases.

Table B-2
12.5 kHz Receiver Interoperability Bench Data

Receiver	25 kHz Desired Signal, S (dBm)	12.5 kHz Desired Signal, S (dBm)
Simplex	-119	-117
Duplex	-118	-117

Radiated Test Procedures

The interoperability of 25 and 12.5 kHz channelized marine VHF radios was tested in a maritime environment by measuring the sensitivity of 25 kHz receivers with a 12.5 transmitter. The sensitivity of the 25 kHz receivers with a 25 kHz transmitter was previously measured during the interference susceptibility tests described in section 4.0 of this report. The sensitivity of 25 kHz receivers to a 12.5 kHz transmitter was performed using the test set-up below in Figure B-3.

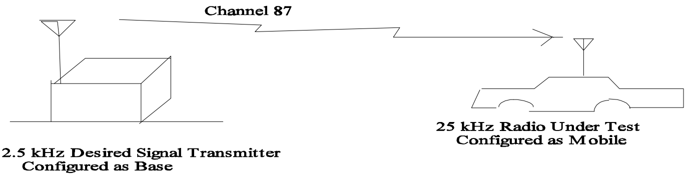

Figure B-3
25 kHz Receiver Interoperability Radiated Test Set-up

The following steps were taken to perform the tests on the 25 kHz radio receivers:

1. The 12.5 kHz radio and the 25 kHz radio being tested were both set to channel 87.

2. The 12.5 kHz radio was modulated by a 1 kHz tone adjusted in amplitude to produce a 2 kHz signal deviation.

3. The RF output of the 12.5 kHz radio was connected to an antenna located on the roof of the test facility.

4. The 25 kHz receiver was located in a car. The RF input to the radio was connected to adjustable RF attenuators and then to a whip antenna mounted on the roof of the car. The 12.5 kHz radio was keyed so that it would transmit.

5. The car then moved 2 miles north of the test facility and stopped. The level of the received desired signal power was then adjusted with the step attenuators till the SINAD of the radio being tested measured 15 dB with the communications test set. At that point the power of the desired signal at the receiver input was measured in dBm with the spectrum analyzer and its value recorded. The location of the car was determined in latitude and longitude with a GPS receiver.

6. Steps one through five were repeated for each radio being tested.

Radiated Test Results

The results of the interoperability tests with a 12.5 kHz transmitter and the 25 kHz receivers are contained below in Table B-3. Column one lists the 25 kHz receiver being tested, column two shows the desired signal power at the 25 kHz receiver input required to produce a 15 dB SINAD from a 12.5 kHz transmitter. Column three shows the desired signal power from a 25 kHz transmitter required to produce the 15 dB SINAD.

Table B-3
25 kHz Receivers Interoperability Radiated Data

25 kHz Radio	**12.5 kHz Desired Signal, S (dBm)**	**25 kHz Desired Signal, S (dBm)**
Receiver A	-115	-107
Receiver B	-119	-126
Receiver E	-113	-108
Receiver F	-115	-105
Receiver G	-116	-111
Receiver H	-115	-113
Receiver I	-116	-124
Receiver K	-116	-112

The locations of the desired signal transmitter and the radio under test are shown below in Table B-4.

Table B-4
Transmitter and Receiver Locations

	Latitude	Longitude
Desired Transmitter	27E 53.147' N	82E 45.679' W
Radio under test	27E 54.943' N	82E 45.976' W

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Appendix C
Intermodulation Test Procedures and Recorded Data

The marine VHF radios were tested for susceptibility to 3rd and 5th order intermodulation products by using two signal generators as interfering transmitters that could possibly generate intermodulation products on channel 67 within the receiver of the radio being tested. A diagram of the test set-up is shown below in Figure C-1.

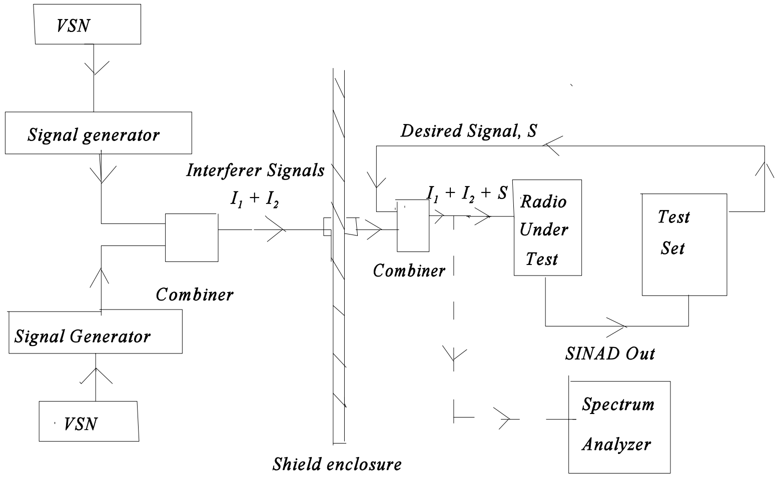

Figure C-1
Intermodulation Susceptibility Test Set-up

The following steps which were taken to perform the intermodulation tests.

1. The receiver of the radio under test was tuned to marine channel 67. The test set which was used as the desired signal transmitter was also tuned to channel 67 and was modulated by an internal 1 kHz tone adjusted in amplitude for a 3 kHz signal deviation.

2. The power of the desired signal, S, from the RF output of the test set was adjusted and its value recorded in dBm when the SINAD of the radio receiver under test was 15 dB.

3. The frequencies of the signal generators were set to values that could generate the 3rd or 5th order intermodulation products on channel 67 within the radio's receiver. Two pairs of frequencies were chosen so that both frequencies of each pair were either in the marine band (156-174 MHz) or both out of the marine band.

4. The RF outputs of the signal generators were FM modulated by voice-shaped noise (VSN) played from tapes in cassette players. The peak amplitudes of the VSN signals from the cassette tapes were

matched as closely as possible to the amplitude of a 1 kHz tone that would produce a 2.5 kHz signal deviation.

5. The RF outputs of the signal generators, I_1 and I_2, were combined and fed through the shielded enclosure. This composite signal was then combined with the desired signal, S, from the test set and connected to the RF input of the radio.

6. The RF power of each signal generator was increased from -139 dBm in equal increments (i.e. , the signal generator RF output levels were kept approximately equal) until the SINAD of the radio being tested dropped from 15 to 12 dB.

7. The SINAD reduction due to intermodulation products was verified by turning each of the signal generators off and observing the SINAD meter on the test set. If the SINAD did not recover to 15 dB with only one signal generator present, then receiver saturation was presumed to be the dominant interference mechanism rather than intermodulation.

7. Once the SINAD reduction due to the intermodulation product was verified, the RF power of each signal generator, I_1 and I_2 , at the RF input to the radio was measured in dBm with a spectrum analyzer and recorded.

8. If receiver saturation occurred, then it was so noted and the tests continued.

The CCIT audio weighting filter in the test set was not activated during these tests.

Setting Frequency Generators

Using equation C-1, two frequencies were selected to generate the 3rd order in-band intermodulation product on channel 67. Note: F1 is tuned below F2.

In band frequencies: F1=158.700 MHz, F2=161.025 MHz

(Eq. C-1) $F_{IM3} = 2F1 - F2$

$F_{IM3} = 2*158.700 - 161.025$

$F_{IM3} = 156.375$ MHz, which is the carrier frequency of marine channel 67

Equation C-2 was used to select frequencies to generate the 3rd order out-of-band intermodulation products on channel 67.

Out-of-band frequencies: F1=151.725 MHz, F2=154.050 MHz

(Eq. C-2) $F_{IM3} = 2F2 - F1$

$F_{IM3} = 2*154.050 - 151.725$

$F_{IM3} = 156.375$ MHz, which is the carrier frequency of marine channel 67

Using equation C-3, two frequencies were selected to generate the 5th order in-band intermodulation product on channel 67. Note: F1 is tuned below F2.

In band frequencies: F1=158.700 MHz, F2=159.8625 MHz

(Eq. C-3) $F_{IM5} = 3F1 - 2F2$

$F_{IM5} = 3*158.700 - 2*159.8625$

$F_{IM5} = 156.375$ MHz, which is the carrier frequency of marine channel 67

Equation C-4 was used to select frequencies to generate the 5th order out-of-band intermodulation product on channel 67.

Out-of-band frequencies: F1=152.8875 MHz, F2=154.050 MHz

(Eq. C-4) $F_{IM5} = 3F2 - 2F1$

$F_{IM5} = 3*154.050 - 2*152.8875$

$F_{IM5} = 156.375$ MHz, which is the carrier frequency of marine channel 67

Calculating Intermodulation Rejection Ratio

The intermodulation rejection ratio (IMR) of the victim receiver was calculated using equation C-5:

(Eq. C-5)
$$IMR = S - I$$

where:

IMR= Intermodulation rejection ratio of victim receiver, in dB

S = Desired signal power for 15 dB SINAD, in dBm

I = Power of interferer, in dBm

The IMR, S, and I for each receiver is shown below in Tables C-1 through C-4. Table C-1 contains the data for the out-of-band response and Table C-2 contains data for the in-band response for 3rd order IMR. The powers of each interferer are almost equal, therefore the S/I was calculated using the nominal value.

Table C-1
In-Band 3rd Order IMR Response

Radio	Desired Signal, S (dBm)	F1= 158.700 MHz F2= 161.025 MHz		
		IMR (dB)	I_1 (dBm)	I_2 (dBm)
Receiver A	-114	-63	-50.8	-50.5
Receiver B	-119	-81	-38.7	-38.2
Receiver C	-117	-77	-40.0	-39.6
Receiver D	-119	-80	-40.6	-40.2
Receiver E	-115	-62	-53.5	-53.2
Receiver F	-116	-78	-38.7	-38.2
Receiver G	-115	-61	-54.2	-53.8
Receiver G	-115	-72	-43.5	-43.2
Receiver I	-117	-67	-50.5	-49.8
Receiver K	-118	-66	-52	-52

Table C-2
Out-of-Band 3rd Order IMR Response

Radio	Desired Signal, S (dBm)	F1= 151.725 MHz F2= 154.050 MHz		
		IMR (dB)	I_1 (dBm)	I_2 (dBm)
Receiver A	-114	-68	-46.0	-46.3
Receiver B	-119	saturation	*	*
Receiver C	-117	-84	-33..5	-32.8
Receiver D	-119	saturation	*	*
Receiver E	-115	-71	-44.3	-42.3
Receiver F	-116	-83	-33.2	-32.6
Receiver G	-115	-71	-44.8	-44.2
Receiver H	-115	saturation	*	*
Receiver I	-117	-71	-46.6	-46.2
Receiver K	-118	-69	-49	-49

Table C-3 contains the data for the out-of-band response and Table C-4 contains data for the in-band response for 5th order IMR.

Table C-3
In-Band 5th Order IMR Response

Radio	**Desired Signal, S (dBm)**	**F1= 158.700 MHz F2= 159.8625 MHz**		
		IMR (dB)	**I_1 (dBm)**	**I_2 (dBm)**
Receiver A	-114	-73	-41.3	-41.0
Receiver B	-119	saturation	*	*
Receiver D	-119	-86	-33	-33
Receiver E	-115	-76	-39	-39
Receiver F	-116	saturation	*	*
Receiver G	-115	saturation	*	*
Receiver H	-115	saturation	*	*
Receiver I	-117	saturation	*	*
Receiver K	-118	-80	-38	-38

Table C-4
Out-of-Band 5th Order IMR Response

Radio	**Desired Signal, S (dBm)**	**F1= 152.8875 MHz F2= 154.050 MHz**		
		IMR (dB)	**I_1 (dBm)**	**I_2 (dBm)**
Receiver A	-114	-77	-37	-37
Receiver B	-119	saturation	*	*
Receiver D	-119	saturation	*	*
Receiver E	-115	-81	-34	-34
Receiver F	-116	saturation	*	*
Receiver G	-115	saturation	*	*
Receiver H	-115	saturation	*	*
Receiver I	-117	-83	-35	-34
Receiver K	-118	-82	-36	-36

The saturation values were not recorded but generally occurred at higher powers than the intermodulation products.

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Appendix D
Transponder Test Procedures

The following steps were used to test the susceptibility of a VTS-like transponder system to a 12.5 kHz interferer tuned 12.5 kHz from the transponder channel carrier. The transponder system operates according to the procedures outlined in ITU-R M.825 with some enhancements. The system is able to update the status information of a participating vessel by interrogating the ship's transponder every 10 seconds. The ship's transponder responds to the interrogations by sending the ship's information (i.e., ship's ID, heading, speed, location, draft, cargo) back to the system controller. This information is then sent by the controller to the other vessels participating in the system. The transponder is considered to be in failure mode if it is not able to reply to the system controller's interrogations for information.

The objective of this test was to inject sufficient adjacent channel interference into the transponder receiver so that it could no longer receive the system controller's interrogations and be put in a failure mode.

The transponder was tested using the set-up shown below in Figure D-1.

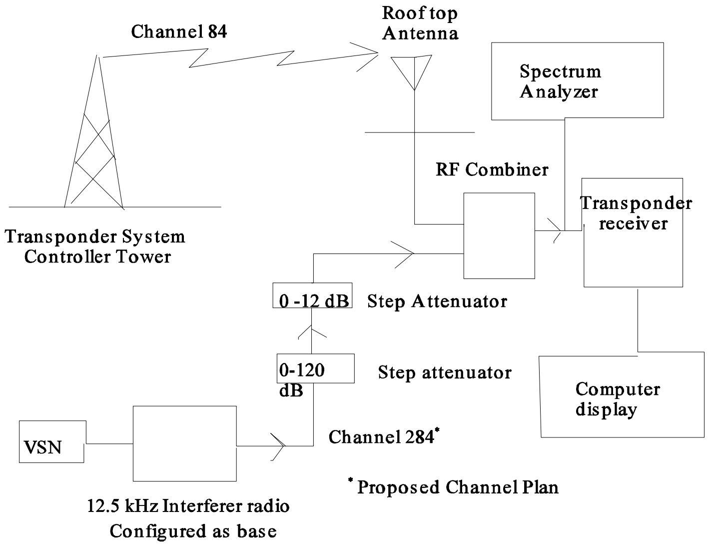

Figure D-1
VTS-Like Transponder Test Set-up

The following steps were taken to perform the transponder tests.

1. The transponder being tested was operating as a stationary unit in the laboratory of the test facility. The transponder was connected to a rooftop antenna and was communicating with the system controller at the test facility via a tower located 3 miles from the building.

2. Since the transponder had already been "acquired" by the system on channel 70, it was now communicating with the system controller on duplex channel 84 as a mobile unit. The 12.5 kHz interferer radio was tuned to channel 284 (the interstitial 12.5 kHz offset from the carrier of channel 84) and was modulated by VSN matched in amplitude to a 1 kHz tone that would produce a 1.5 kHz signal deviation. The interferer was configured as a base unit operating on the interstitial channel.

3. The RF output of the interferer radio was connected to a 3 dB attenuator and then to adjustable RF step attenuators. The output of the attenuators was then connected to one input of a 2-to-1 RF combiner. The other input to the combiner was connected to the cable of the rooftop antenna. The output of the combiner was then connected to the RF input of the transponder receiver.

4. The attenuators were set to their maximum value and the interferer radio was keyed up so that it would inject interference into the transponder.

5. The power of the adjacent channel interference was increased by decreasing the value of the step attenuators so that the interferer would disrupt the transponder operations. The power of the interferer was increased till the transponder could no longer respond to the system controller's interrogations. When the transponder was in failure mode, the power of the interferer at the input to the transponder was measured in dBm with the spectrum analyzer and its value recorded.

Transponder Test Results

The transponder was able to respond to the controller's polls and reach a 50% reply rate with an interference power of -26 dBm injected into its RF input on an adjacent interstitial channel. The transponder was unable to receive interrogations with an interference power of -25 dBm injected into its RF input and was considered to be in failure mode. These tests were performed while the transponder was in "distance mode". By switching to "local mode" the transponder could withstand an additional 2-3 dB of interference power before failure occurred.

The desired transponder signal measured at the input to the transponder receiver was approximately -60 dBm. The Signal-to-Interference (S/I) ratio for the 50% reply rate for the transponder receiver was -34 dB and the S/I ratio for failure mode was -35 dB.

Appendix E

Calculating Adjacent Channel Separation and Interoperability Distances

Calculating Required Path Loss and Corresponding Distance

Adjacent channel separation and interoperability distances were calculated for the 25 kHz and 12.5 kHz receivers by first determining the required path loss by using the following equations and assumptions:

(Eq. E-1) $P_R = P_T + G_T + G_R - L_S - L_P$

where:

P_R = Power at receiver input (defined below), dBm
P_T = Transmitter Power, dBm
G_T = Transmitter Antenna Gain Towards Receiver, dBi
G_R = Receiver Antenna gain Towards Transmitter, dBi
L_S = System Loss, dB
L_P = Required Path Loss, dB

with:

P_T = 44, 37, and 30 dBm
G_T = 3 dBi
G_R = 3 dBi
L_S = 2 dB

Rearranging equation E-1 to solve for the required path loss, L_P, results in equation E-2.

(Eq. E-2) $L_P = P_T + G_T + G_R - L_S - P_R$

For the adjacent channel separation distances, the required path loss was calculated by using the above assumptions and setting the received power, P_R, equal to the received interference power values in Tables A-1, A-2, and A-7 of Appendix A.

For the interoperability distances, the required path loss was calculated by using the above assumptions and setting the received power, P_R, equal to the received desired signal power values in Tables B-1 and B-2 of Appendix B.

Once the required path loss values were calculated, the adjacent channel separation and interoperability distances were determined by reading the appropriate value of distance that corresponds to the required path loss on Figures E-1, E-2, and E-3. These figures were created using the NTIA nlambda propagation model for smooth earth at 157.1 MHz over seawater with vertical polarization at the 50 percentile. Three cases of transmit and receive antenna heights were considered: 3 m, 3 and 10 m, and 10 m. These cases were done to model communications between recreational boaters, recreational and commercial boaters, and commercial boaters. Higher antenna heights increase the radio line-of-sight distance and alter the path loss values.

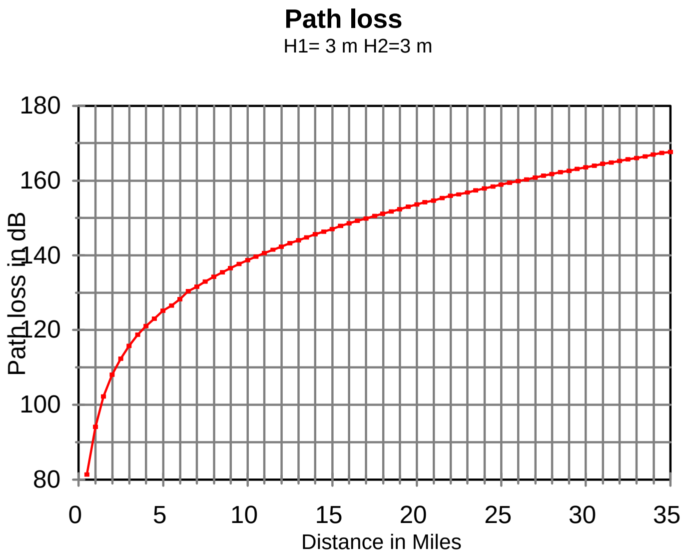

Figure E-1
Path Loss Distance Curve, 3 m and 3 m

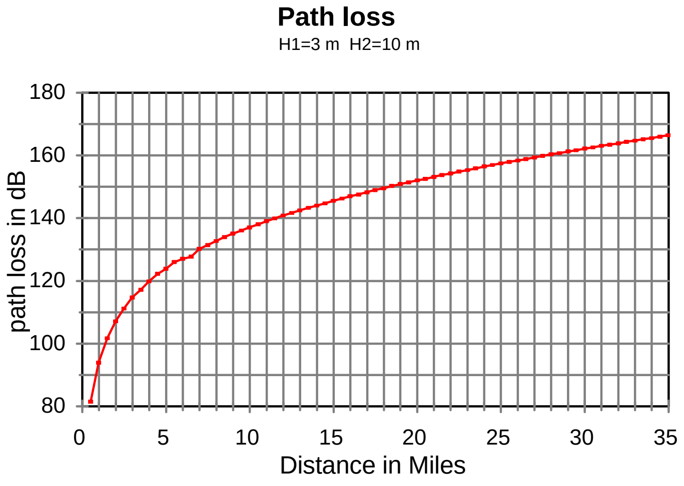

Figure E-2
Path Loss Distance Curve, 3 m and 10 m

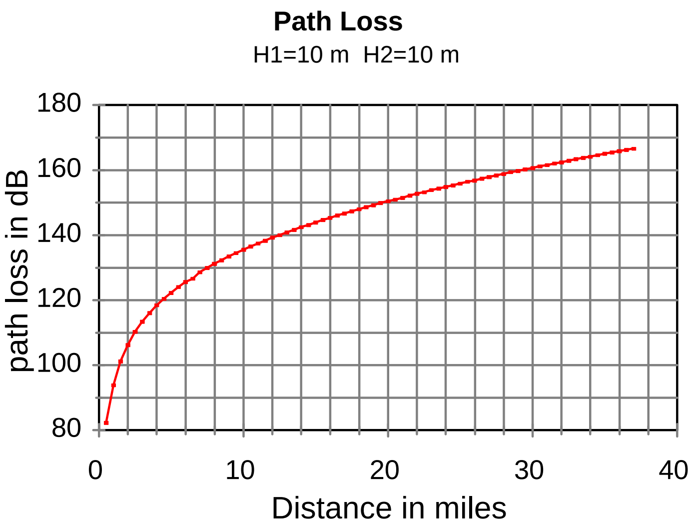

Figure E-3
Path Loss Distance Curve, 10 m and 10 m

Sample Calculations

The following paragraphs contain sample calculations for determining the adjacent channel separation and interoperability distances for receiver A, a 25 kHz radio. The same methodology applies to all other 25 and 12.5 kHz radios.

Adjacent Channel Separation Distance

The received interference power for Receiver A in column four of Table A-1 is -59 dBm for a 25 kHz interferer off-tuned by -25 kHz from the desired signal. The received interference power for receiver A from a 12.5 kHz interferer off-tuned by 12.5 kHz is -97 dBm (column 6 of Table A-2).

Setting P_R in equation E-2 equal to -59 and -97 dBm and using the other assumptions, the required path loss can be calculated for receiver A versus the 25 kHz and 12.5 kHz interferers at each level of interferer transmitter power. The results are 107, 100 and 93 dB, and 145, 138 and 131 dB, respectively.

The corresponding distance for each required path loss can then be determined by using the appropriate figure for the selected antenna heights. For example, for a required path loss of 107 dB the corresponding distance for antenna heights of 3 meters can be determined from Figure E-1 to be approximately 1.5 miles. For a required path loss of 145 dB, the corresponding distance for antenna heights of 3 meters can be determined from Figure E-1 to be approximately 13.5 miles. Figure E-2 can be used to determine the adjacent separation distances for antenna heights of 3 and 10 meters. Figure E-3 can be used to determine the adjacent channel separation distances for antenna heights of 10 meters.

Adjacent channel separation distances for different scenarios/situations can be determined from the figures by changing the assumptions for antenna gain and system loss in equation E-2.

Interoperability Distance

The desired signal power for Receiver A in column two of Table B-1 is -111 dBm for a 12.5 kHz transmitter and in column three is -114 dBm for a 25 kHz transmitter.

Setting P_R in equation E-2 equal to -111 and -114 dBm and using the other assumptions, the required path loss can be calculated for receiver A communicating with the 12.5 kHz and 25 kHz transmitters. The results are 159, 152 and 145 dB, and 162, 155 and 148 dB, respectively.

The corresponding distance for each required path loss can then be determined by using the appropriate figure for the selected antenna heights. For example, for a required path loss of 159 dB, the corresponding distance for antenna heights of 3 meters can be determined from Figure E-1 to be approximately 25 miles. For a required path loss of 162 dB, the corresponding distance for antenna heights of 3 meters can be determined from Figure E-1 to be approximately 28 miles. Figure E-2 can be used to determine the interoperability distances for antenna heights of 3 and 10 meters. Figure E-3 can be used to determine the interoperability distances for antenna heights of 10 meters.

Interoperability distances for different scenarios/situations can be determined from the figures by changing the assumptions for antenna gain and system loss in equation E-2.

Conversion To Nautical Miles

The distances chosen from the figures are in statute miles. They were converted to nautical miles in the main report by multiplying by .87.

Appendix F
Test Frequencies

Bench Test Frequencies

The following paragraphs describe the frequencies\channels used during the adjacent channel interference susceptibility and interoperability bench tests.

Adjacent Channel Interference Tests

The 25 kHz radios were tested for susceptibility to adjacent channel interference on simplex and duplex channels. The 25 kHz radios were tested with both 25 and 12.5 kHz channelized radios acting as the interferers. The 25 kHz interferers were tuned ±25 and ±50 kHz (two channels) from the desired signal carrier frequency and the 12.5 kHz interferers were tuned ±12.5, ±25, ±37.5, and ±50 kHz from the carrier frequency. Using this method a "baseline" measurement of the current operating 25 kHz environment could be simulated and those results compared to the proposed 25 and 12.5 kHz environment.

The frequencies that were used by the desired signal and interferer radio during the simplex interference susceptibility testing are shown below in Table F-1. The desired signal was transmitted on channel 22A. On-tune interferers were not tested. The interstitial channel designations for the interferers in Tables F-1 and F-2 are identified by adding a prefix of "2" to the previous 25 kHz channel. For example, the interstitial channel 12.5 kHz above channel 21 is labeled 221. This channel plan designation has been submitted to ITU-R study group 8B but has not yet been internationally adopted.

Table F-1
25 kHz Simplex Test Channels

Simplex Channel Designation	Interferer Frequency (MHz)	offset value kHz
21A	157.0500	-50.0
221*	157.0625	-37.5
81A	157.0750	-25.0
281*	157.0875	-12.5
22 A	**157.1000**	**0**
222*	157.1125	+12.5
82A	157.1250	+25.0
282*	157.1375	+37.5
23A	157.1500	+50.0
* proposed designator		

The frequencies that were used by the desired signal and interferer radio during the duplex interference susceptibility testing are shown below in Table A-2. Channel 87 was the desired signal channel.

Table F-2
25 kHz Duplex Test Frequencies

Duplex Channel Designation	Transmit Mobile Stations (MHz)	Transmit Base Stations (MHz)	Offset value (kHz)
86	157.3250	161.9250	-50.0
286*	157.3375	161.9375	-37.5
27	157.3500	161.9500	-25.0
227*	157.3625	161.9625	-12.5
87	**157.3750**	**161.9750**	**0**
287*	157.3875	161.9875	+12.5
28	157.4000	162.0000	+25.0
228*	157.4125	162.0125	+37.5
88	157.4250	162.0250	+50.0
* proposed designator			

When testing the 25 kHz mobile receiver on the duplex channel, the test set functioned as the desired base station transmitter and the interferer radio located outside the shield room acted as the adjacently tuned base station 25 or 12.5 kHz transmitter. Conversely, when testing the 25 kHz base station receiver on the duplex channel the test set functioned as the desired mobile transmitter and the interferer radios acted as the adjacently tuned mobile transmitter.

The radios were configured as either a base station or mobile unit. Therefore, the tests were completed by merely selecting the proper channel for each test set-up. Internal programming in the radios selected the proper frequency for that particular desired and interferer channel for each test. Most marine VHF radios are sold either as a base station radio or as a mobile radio. Although, some manufacturers sell radios that can be configured by the user as either one.

Note: In Tables F-1 and F-2 the 25 kHz interferers transmitted only on the assigned marine channels. The 12.5 kHz interferers transmitted on the assigned marine channels and the interstitial channels between them.

The 12.5 kHz radios were tested for susceptibility to adjacent channel interference on simplex and duplex channels. The 12.5 kHz radios were only tested with 25 kHz channelized radios acting as the interferers. The 25 kHz interferer radios were off-tuned ±12.5 and ±37.5 kHz from the carrier frequency of the desired 12.5 kHz signal. Table F-3 lists the frequencies of the simplex desired and interferer channels tested. The interstitial channel 222A was the desired signal channel. Obviously, due to the channel plan an on-tune 25 kHz interferer could not be tested.

Table F-3
12.5 kHz Simplex Test Frequencies

Simplex Channel Designation	Interferer Frequency (MHz)	offset value (kHz)
81A	157.0750	-37.5
22A	157.1000	-12.5
222A*	**157.1125**	**0**
82A	157.1250	+12.5
23A	157.1500	+37.5
* proposed designator		

Table F-4 lists the frequencies of the duplex desired and interferer channels. The interstitial channel 285 was the desired signal channel.

Table F-4
12.5 kHz Duplex Test Frequencies

Duplex Channel Designation	Transmit Mobile Stations (MHz)	Transmit Base Stations (MHz)	Offset value (kHz)
25	157.2500	161.8500	-37.5
85	157.2750	161.8750	-12.5
285*	**157.2875**	**161.8875**	**0**
26	157.3000	161.9000	+12.5
86	157.3250	161.9250	+37.5
* proposed designator			

When testing the 12.5 kHz mobile and base receiver on the duplex and simplex channel the test set functioned as the adjacently tuned 25 kHz interferer radio. This was accomplished by adjusting the carrier frequency of the RF output of the test set to the values shown in Table F-4.

Interoperability Tests

Simplex channel 22A was used as the desired signal channel for testing the interoperability of a 12.5 kHz transmitter with the 25 kHz receivers. Channel 22A was also used to test the interoperability of a 25 kHz transmitter with a 12.5 kHz receiver on a simplex channel. Channel 85 was used to test the interoperability of a 25 kHz transmitter and 12.5 kHz receiver on a duplex channel. The frequencies of these channels are shown above in Tables F-1 and F-2.

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Appendix G
Spectrum Emission Figures

The emission spectra of the test set, a 25 kHz radio, and a 12.5 kHz radio were measured with a spectrum analyzer and recorded with a computer. The results are shown in figures on the following pages. The type of modulating signal and the amount of signal deviation is included in the title of each figure.

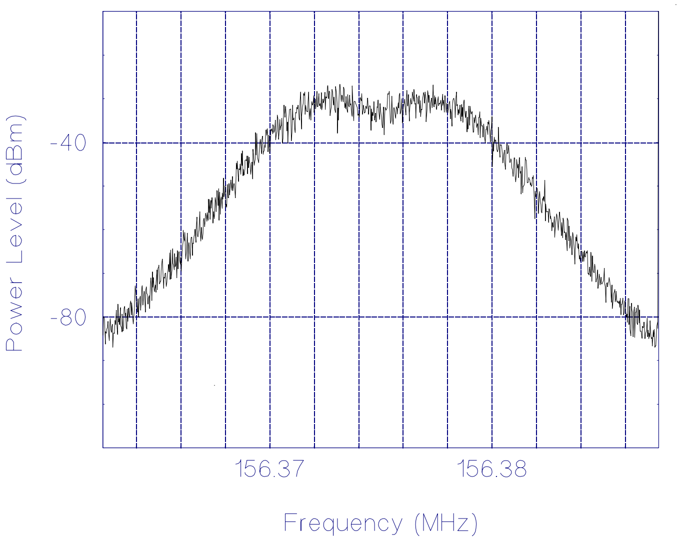

Figure G-1
Test Set with VSN modulation and 3 kHz Deviation

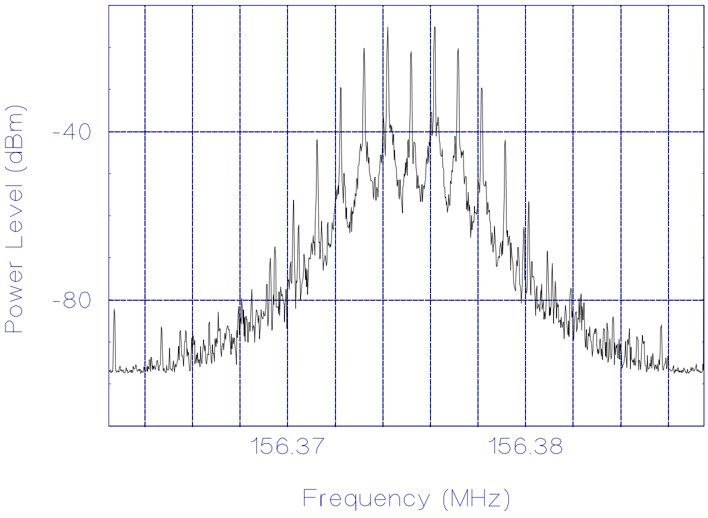

Figure G-2
Test Set with 1 kHz modulation and 3 kHz Deviation, High Output

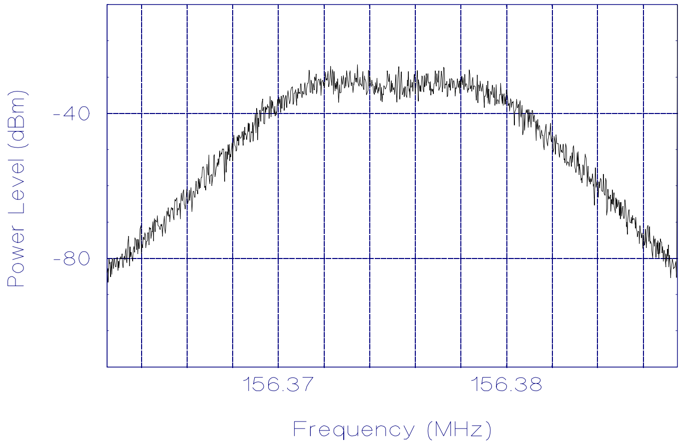

Figure G-3
Test Set with VSN modulation and 2.5 kHz Deviation

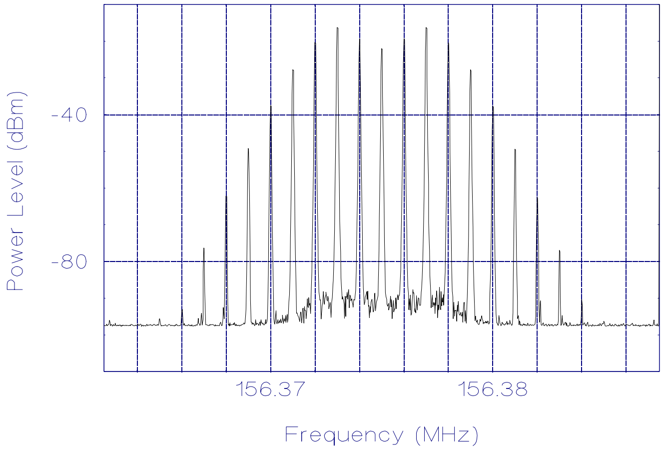

Figure G-4
Test Set with 1 kHz modulation and 2.5 kHz Deviation, High Output

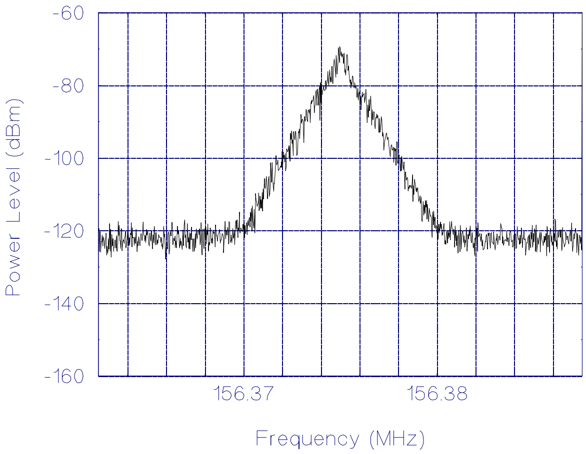

Figure G-5
25 kHz radio with VSN modulation and 3 kHz Deviation

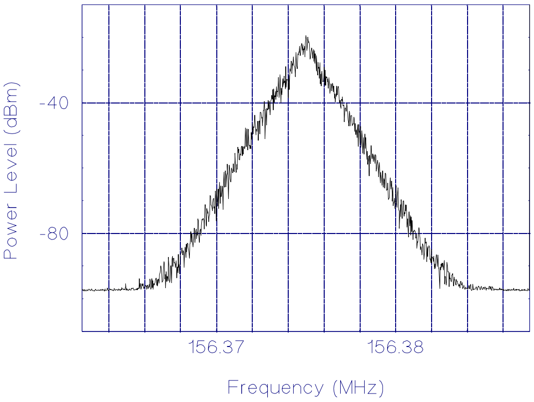

Figure G-6
25 kHz radio with VSN modulation and 2.5 kHz Deviation

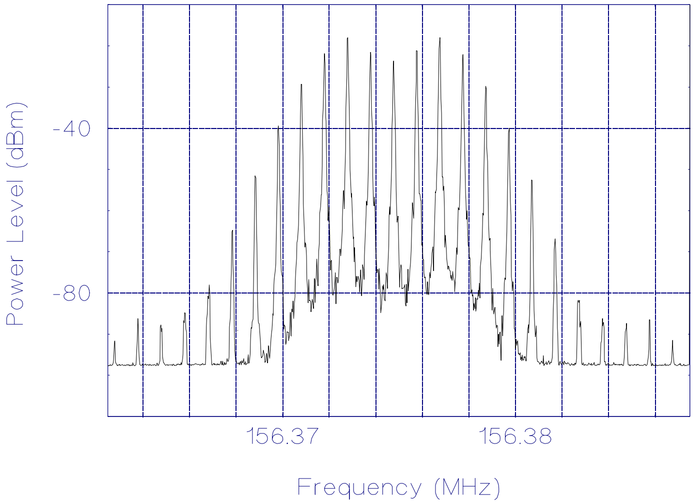

Figure G-7
25 kHz radio with 1kHz modulation and 3 kHz Deviation, High Output

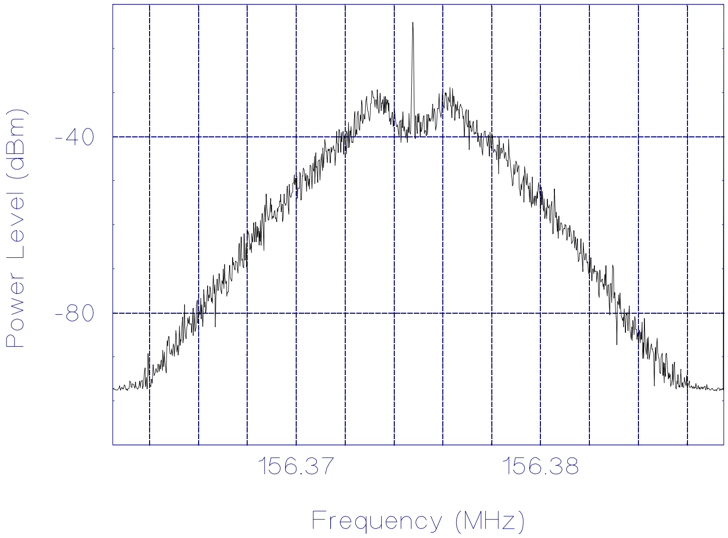

Figure G-8
25 kHz radio with VSN modulation and 2.5 kHz Deviation, High Output

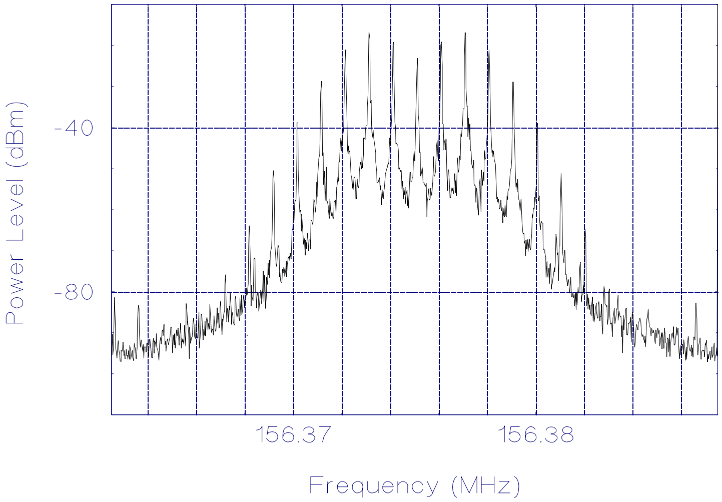

Figure G-9
12.5 kHz radio with 1kHz modulation and 2 kHz Deviation, High Output

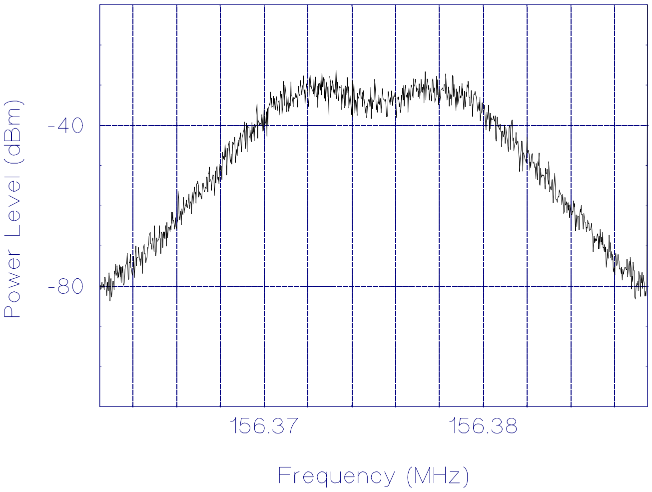

Figure G-10
12.5 kHz radio with VSN modulation and 1.5 kHz Deviation

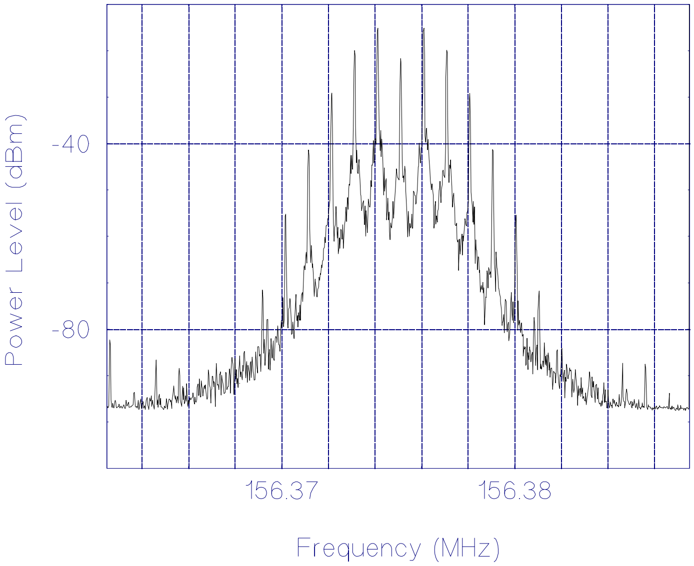

Figure G-11
12.5 kHz radio with 1kHz modulation and 1.5 kHz Deviation, High Output