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Lower Mississippi River VTS Frequency Survey

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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. One type of service that can enhance these functions is called a Vessel Traffic Service (VTS). The VTS will enable ships and shore stations to automatically transmit and receive information between themselves in coastal and port areas and inland waterways. Ships will also be able to automatically exchange information on the high seas. The ships and shore stations will be able to exchange data on ship size, speed, location, heading, cargo and other pertinent information, such as navigation hazards and pollution spills.

The Coast Guard plans to operate an Automatic Independent Surveillance (AIS) digital selective calling (DSC) based transponder system as part of the Ports and Waterways Safety System (PAWWS) in the lower Mississippi River. The service area for this Vessel Traffic Service (VTS) system ranges from a 20 mile radius around the sea buoy located at the mouth of the Southwest Pass entrance of the Mississippi River, to river mile 255 above Baton Rogue.

In a VTS area served by a shore side monitor, the system requires at least one dedicated duplex marine VHF channel for digital data transmissions. One frequency of the duplex pair is used for transponder-to-base station communications and is known as the A side of the channel. The other frequency of the duplex pair is used for base station-to-transponder communications and is known as the B side of the channel. Large VTS areas such as the lower Mississippi River will require additional duplex channels for signal coverage and some type of frequency re-use plan. In areas not served by a VTS shore based monitor, a simplex channel is used for ship-to-ship operations. A report published by NTIA which has been coordinated with the maritime community, NTIA TR-343 "*Assessment of Compatibility Between 25 and 12.5 kHz Channelized Marine VHF Radios*" concluded that a VTS like system could operate on interstitial channels as long as it was assigned frequencies in coordinated areas, such as duplex channels allocated to public correspondence services. However, additional studies performed by NTIA for the Coast Guard and Radio Technical Commission for Maritime Services (RTCM) Special Committee (SC)-117 have shown that the maritime mobile VHF band in the New Orleans is shared with numerous land mobile transmitters and NOAA VHF weather broadcasts. These transmitters are known to cause interference in some VHF marine radios and may also interfere with AIS operations.

Therefore, to ensure that the VTS AIS system operates with a minimal amount of RF interference on its VHF data links, the Coast Guard requested that NTIA survey the duplex public correspondence channels and the interstitial channels between them for interference and evaluate their potential to be used as AIS data channels. In addition, the interstitial channels on the edge of the public correspondence channels were monitored for interference. Personnel from NTIA and the Institute of Telecommunication Sciences (ITS) performed shipboard tests August 10-14, 1998 and shore based tests September 5-9, 1998 to complete these tasks.

The evaluation of the channels potential for use as AIS data channels was based on SINAD histographs and SINAD maps that were produced based on data collected during the tests. The histographs and SINAD maps of the interstitial channels show that they have potential for use as AIS data channels. However, additional tests should be conducted with crystal filters installed at each shore station which will provide the base stations receiver

additional protection from adjacent channel radio operations.

NTIA recommends that the Coast Guard develop a strategy for planning and coordinating, the use of the interstitial and public correspondence channels for AIS operations, with the auction winners in each district that the Coast Guard intends to operate a VTS system. Furthermore, channels that are identified as possible VTS channels should be dedicated to AIS operations and not be shared with any other types of services or functions so that the VTS system can operate with a minimal amount of RF interference to enhance its safety and reliability.

Table of Contents

Section 1. Introduction
1.1 Background 1-1
1.2 Test Objectives 1-2
1.3 Test Procedures 1-2
1.3.1 Ship Receive 1-3
1.3.2 Base Receive 1-5

Section 2. Test Results
2.1 Ship Receive Interstitial Channel Histographs 2-1
2.2 Base Receive Interstitial Channel Histographs 2-5
2.3 Ship Receive Interstitial Channel SINAD Maps 2-7

Section 3 Conclusions and Recommendations 3-1

Appendix A: Ship Receive Interstitial Channel Histographs A-1

Appendix B: Ship Receive Interstitial Channel SINAD Maps B-1

Appendix C: Base Receive Interstitial Channel Histographs C-1

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SECTION 1
INTRODUCTION

1.1 Background

The Coast Guard plans to operate an Automatic Independent Surveillance (AIS) Digital Selective Calling (DSC) based transponder system as part of the Ports and Waterways Safety System (PAWWS) in the lower Mississippi River. The service area for this Vessel Traffic Service (VTS) system ranges from a 20 mile radius around the sea buoy located at the mouth of the Southwest Pass entrance of the Mississippi River to a point 20 miles above Baton Rogue. The implementation of this system in the lower Mississippi river requires at least two dedicated duplex marine VHF channels for its operation with a channel re-use plan. The channels will be used to transmit digital data to/from transponder units and five base stations. These channels are needed to provide signal coverage for ship-to-shore and shore-to-ship communications throughout the VTS operating area, including those areas not served by a shore side monitor for ship-to-ship operations. A VTS center located in New Orleans will coordinate the flow of data to/from the base stations and display vessel information to Coast Guard watch standers.

The Coast Guard has obtained frequency assignments for five duplex channel pairs for use as AIS data channels and five assignments for voice channels. However, the frequency pairs of the channel assignments used for the ship-to-shore and shore-to-ship duplex data channels are not in conformance with Appendix 18 of the ITU Radio Regulations. Furthermore, the ship-to-shore side of the data channels are accessible by mariners for voice communications. Voice communications on both the ship-to-shore and shore-to-ship side of the data channels are disruptive to AIS data transmissions. The data links will have a higher data packet throughput if the channels are not accessible by mariners for voice communications and are not shared with other services. The interstitial channels located between the public correspondence channels are attractive for AIS operations for those reasons. They are "new" channels in the VHF band with a limited number of assignments on them.

A report published by NTIA which has been coordinated with the maritime community, NTIA TR-343 "*Assessment of Compatibility Between 25 and 12.5 kHz Channelized Marine VHF Radios*" concluded that a VTS like system could operate on interstitial channels as long as it was assigned frequencies in coordinated areas, such as duplex channels allocated to public correspondence services. In the US duplex public correspondence channels are licensed by the FCC to operate on marine channels 24, 25, 26, 27, 28, 84, 85, 86, and 87. The interstitial duplex channels are identified as 224, 225, 226, 227, 284, 285, 286, and 287. The border interstitial channels are identified as 283 and 228. The FCC has auctioned channels 24 to 28 and the interstitial channels 224 to 287.

The transponder transmit frequencies are identified as the "A" side of the duplex channel and are used for ship-to-shore communications. The base stations transmit frequencies are identified as the "B" side of the duplex channel and are used for shore-to-ship communications. The frequencies of these channels are shown in Table 1-1. A diagram of the system is shown in Figure 1-1.

Table 1-1
Duplex Channel Frequencies

Duplex Channel Designation	Transponder Transmit Frequency (MHz) A Side	Base Station Transmit Frequency (MHz) B Side
283	157.1875	161.7875
24	157.2000	161.8000
224	157.2125	161.8125
84	157.2250	161.8250
284	157.2375	161.8375
25	157.2500	161.8500
225	157.2625	161.8625
85	157.2750	161.8750
285	157.2875	161.8875
26	157.3000	161.9000
226	157.3125	161.9125
86	157.3250	161.9250
286	157.3375	161.9375
27	157.3500	161.9500
227	157.3625	161.9625
87	157.3750	161.9750
287	157.3875	161.9875
28	157.4000	162.0000
228	157.4125	162.0125

1.2 Introduction

NTIA TR-343 identified duplex interstitial channels as possible candidate frequencies for AIS data channels. However, additional studies performed by NTIA for the Coast Guard have shown that the maritime VHF band in the New Orleans area is shared with land mobile transmitters operating under FCC Parts 22 and 90 Title 47 Code of Federal Regulations. There are also high powered NOAA VHF weather broadcasts in the VTS service area. These transmitters generate interference in maritime VHF radio receivers operating in the New Orleans and Baton Rouge areas. This interference reduces the capability of the mariners to use channels in the band for their communication and safety functions. These same transmitters may also cause interference in the AIS transponder and base station receivers that operate in the band. Therefore, the AIS data channels should be carefully chosen so that the VTS transponders and base stations can operate with a minimal amount of radio interference. To help choose the AIS data channels, the Coast Guard requested that NTIA and ITS survey the A and B sides of the public correspondence channels and associated interstitial channels for interference and evaluate their potential use for AIS operations. The interstitial channels that border the public correspondence channels were also monitored for interference. The methods and test set-ups that were used to accomplish these tasks are described in the section 1.3 of this report.

1.3 Test Procedures

The transponder receive side of each channel shown in Table 1-1 was monitored for interference onboard a Coast Guard Auxiliary vessel during the week of August 10-14, 1998. The test area encompassed the length of the Mississippi river from the sea buoy at Southwest Pass to river mile 255 above Baton Rouge, Louisiana. The channels were monitored for interference with a fixed mount VHF radio that can operate its receiver in local and distance modes. The sensitivity of the receiver for a 20 dB SINAD in local mode is about -107 dBm and in distance mode is about -117 dBm. The speed of the ship was kept under 15 mph so that the distance between consecutive measurements on the same frequency would be under 1 mile. A spectrum analyzer was also used during these tests to observe and record the electromagnetic environment.

The base station receive side of each channel shown in Table 1-1 was monitored for interference at each of the five communication tower sites during October 5-9, 1998. This testing utilized the system receive antenna located on the tower and the same fixed mount VHF radio that was used on the ship. However, because it was anticipated that the base station receiver would not operate in local mode, measurements were only made with the VHF radio receiver set to distance mode.

1.3.1 Ship Receive Test Procedures

The test set-up used to survey the transponder receive side of the channels in Table 1-1 is shown below in Figure 1-1. It was computer controlled and sequentially monitored the B side of each channel for interference by measuring the radio receiver's SINAD as the ship traversed the river. A DGPS receiver was used to note the location on the river where the SINAD measurement was made.

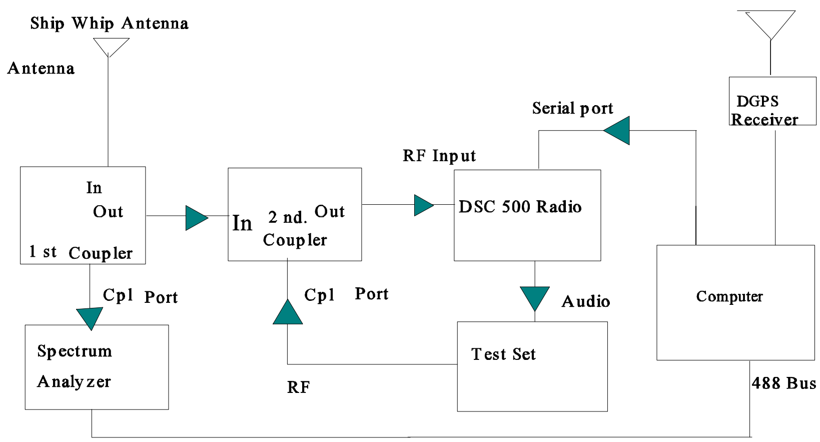

Figure 1-1
Shipboard Test Set-up

The following steps were used to survey the selected channels for interference on the Mississippi River.

1. The equipment in Figure 1-1 was installed on the Coast Guard Auxiliary vessel.

2. The computer tuned the radio and test set to the selected channel via the serial port and IEEE 488 interface. The computer also set the radio receiver to distance or local mode. Coax cable was used to connect a 10 foot whip antenna mounted on the flying bridge of the ship to the input of the first coupler.

3. The RF power output of the test set (which also functioned as the signal generator) was set by the computer to produce a 20 dB SINAD without interference being present for the selected frequency. The modulating signal was

a 1 kHz tone adjusted in amplitude to produce a 3 kHz signal deviation for 25 kHz channels and 2 kHz for interstitial channels. The RF power was adjusted to produce a 20 dB SINAD for each channel when the step was repeated. The required RF power output for each channel's 20 dB SINAD, for local and distance mode, was previously measured in the laboratory and stored in the computer.

4. The computer read the receiver SINAD value as measured by the test set with the ship's antenna connected into the circuit and the ship's location using the DGPS receiver. The following parameters were recorded by the computer into a data file: channel #, SINAD, time, and location. If the SINAD was below 14 dB or more than 15 minutes elapsed since the last spectrum sweep then, in addition to the above mentioned data, the computer also instructed the spectrum analyzer to sweep the 150-168 MHz band and record the power and frequency of the emitters that were present.

5. The computer set the receiver to local mode and steps 3 and 4 were repeated.

6 The computer set the receiver to the next channel (listed in Table 1-1) and steps 2 through 5 were repeated.

The measurements were conducted from 7:00 am to 6:00 p.m. to coincide with the peak land mobile transmitter activity.

1.3.2 Base Receive Test Procedures

The A side of the channels in Table 1-1 were monitored for interference using the test set-up shown in Figure 1-2. The procedures used for this test set-up are outlined in the following paragraphs. In this test set-up, the bandpass filter of the RF cabinet at each communications site was used as a pre-selector for the DSC-500 radio that was used for SINAD measurements.

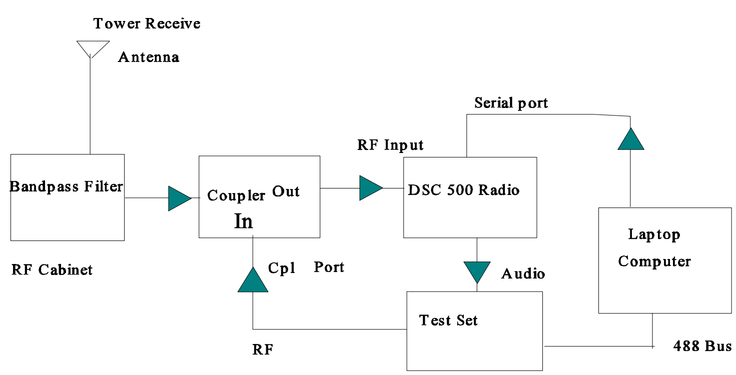

Figure 1-2
Base Receive Test Set-up

The following steps were used to monitor the selected channels for interference at the base stations.

1. The equipment in Figure 1-2 was placed inside the communications equipment building at each high site.

2. The computer tuned the radio and the test set to the selected channel. The test set also functioned as the desired signal generator. The computer set the radio receiver to distance mode. Coax cable was used to connect the output of the RF cabinet band pass filter to the input of the RF combiner.

3. The RF power output of the test set, which was connected to the other port of the RF combiner, was set by the computer to produce a 21 dB SINAD for the selected frequency without interference being present. The modulating signal was a 1 kHz tone adjusted in amplitude to produce a 3 kHz signal deviation for 25 kHz channels and 2 kHz for interstitial channels. The RF power was adjusted to produce a 21 dB SINAD for each channel when the step was repeated. The required RF power output for each channel's 21 dB SINAD was previously measured in the laboratory and stored in the computer.

4. The communications site antenna was connected into the circuit and the computer read the receiver SINAD value as measured by the test set. The SINAD measurement was then stored in a data file. The channel was monitored for fifteen minutes.

5 The computer set the receiver to the next channel in Table 1-1 and steps three and four were repeated.

The measurements were conducted from 7:00 am to 6:00 p.m. to coincide with the peak land mobile transmitter activity.

SECTION 2
TEST RESULTS

2. Test Results

SINAD histographs and SINAD maps have been produced based on the data collected during the tests. Appendix A contains histographs for the ship receive side of each interstitial channel in Table 1-1 for the mobile receiver operating in local and distance mode. Appendix B contains the SINAD maps for the transponder receive (B sides) of channels 228 and 283 for local and distance mode operation. Appendix C contains histographs for the base station receive side of each interstitial channel in Table 1-1.

The system will most likely use interstitial channels for data communications once it achieves operational status, therefore histographs and SINAD maps for the 25 kHz duplex channels shown in Table 1-1 are not included in this report. However, data for the 25 kHz channels is archived and histographs and SINAD maps of the channels can be produced if the need arises.

2.1 SINAD Histographs

SINAD histographs can be used to determine which channels would be appropriate choices for AIS services . They are a graphical representation of the percentage of time versus SINAD dB value. Histographs with a greater distribution of SINAD measurements to higher dB values for a higher percentage of time indicate that the channel is less likely to have interference present and therefore be a good choice for AIS operations. Histographs that show the major portions of the SINAD distributions above 16 dB indicate that the channel has good potential for AIS operations.

2.1 Ship Receive Histographs

The ship receive histographs give an indication of how well the B side of the channel would function as the communications link from the base station to the transponder. Ship receive side histographs that show a high distribution of SINAD values to high values for a greater percentage of time means that the transponder should be able to respond to base station commands and receive relayed text/data messages when using that side of the channel.

Histographs of the ship receive side of interstitial channels 228 and 283 with the receiver set to local and distance modes are shown below in Figures 2-1 through and 2-4. They are a summary of the SINAD measurements that were taken as the ship traversed the length of the VTS service. SINAD measurements of specific segments of the river are represented by the SINAD maps shown in Appendix B.

The histographs for all of the interstitial channels in Table 1-1 are shown in Appendix A.

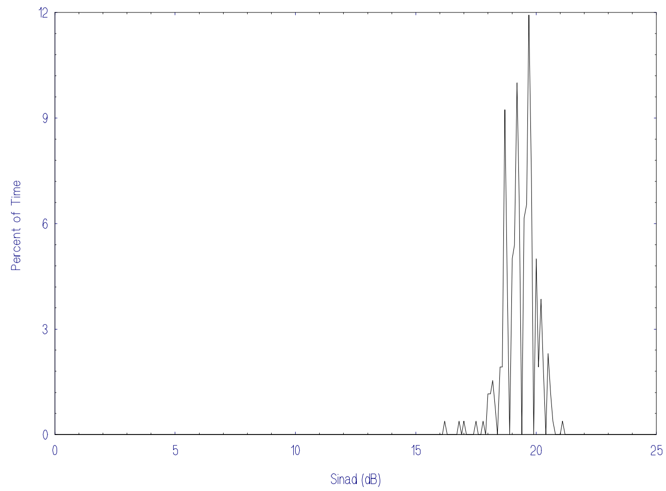

Figure 2-1
Channel 283 Ship Receive Local Mode

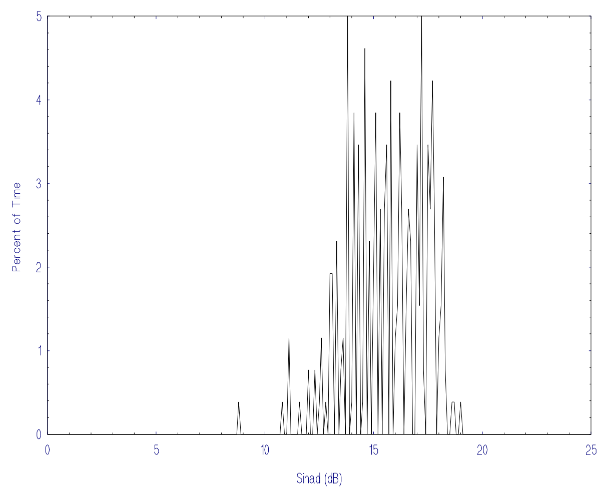

Figure 2-2
Channel 283 Ship Receive Distance Mode

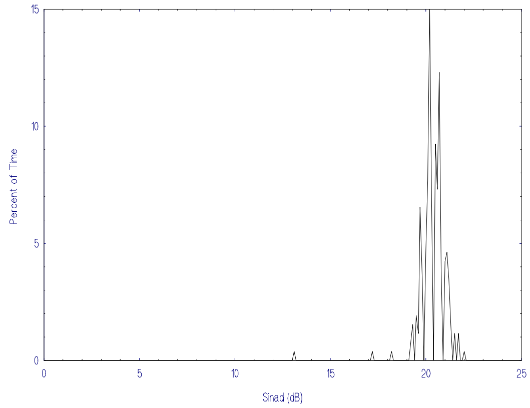

Figure 2-3
Channel 228 Ship Receive Local Mode

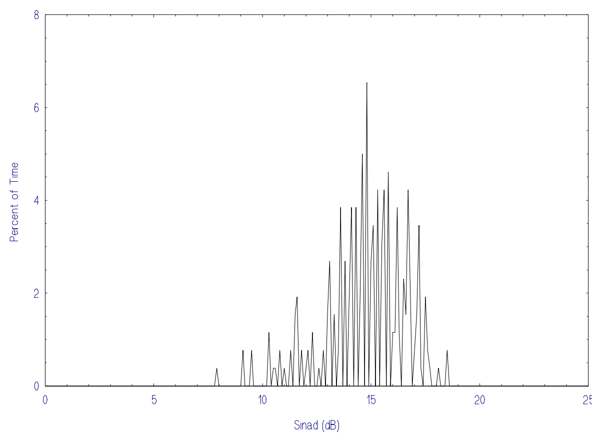

Figure 2-4
Channel 228 Ship Receive Distance Mode

Figures 2-1 and 2-2 show that ship receive side of channel 283 may be a good choice for AIS operations. In local mode the major portion of the SINAD distributions are within the 17-21 dB range and for distance mode the major distribution is in the 14-18 dB range. Figures 2-3 and 2-4 show that the ship receive side of channel 228 may also be a good choice for AIS operations for the same reasons. In local mode the major portion of the SINAD distribution is in the 19-22 dB range and 14-18 dB in distance mode. The system should have a high data/message throughput from the base station to the transponder using the B side of these channels because the SINAD values are generally above 16 dB with the receiver operating in local and distance mode. Therefore the base station to transponder link would function well on the B sides of channels 283 and 228 if the transponder receiver were operated in distance mode or local mode.

Reviewing the histographs in Appendix A of all the ship receive sides of the interstitial channels and comparing the distribution of their SINAD measurements, it can be seen that the deviation of the SINAD distributions between the B sides of the interstitial channels is not significant. The major portion of the SINAD distributions for the B sides of the interstitial channels are in the 13-17 dB range for distance mode and 18-21 dB in local mode. Therefore, the B side of each channel has the potential to be used as an AIS data channel for the base station to transponder link.

2.1 Base Receive Histographs

Histographs of the base receive side of the channels give an indication of how well the A side of the channel would function as the link from the transponder to the base station. Histographs of the base receive sides of the channels with a greater distribution of SINAD measurements above 16 dB means that the base station should be able to receive a high percentage of the transponder position reports and text messages using that channel. Histographs of the base receive side of the channels with a greater distribution of SINAD measurements to low values means that interference on this side of the duplex channel could disrupt the communications link from the transponders to base stations, causing the base station receiver to miss transponder position reports, text messages, and command acknowledgments.

Histographs of the base receive sides of the interstitial channels in Appendix C are a combination of the measurements taken at the five communication sites for each frequency represented as one graph. The histographs were prepared this way because three of the five sites will use one frequency and the other two sites will use the other one. Data is available to produce histographs for all channels at each site. For example, the histograph for the base receive side of channel 283 shown below in Figure 2-5 was made from measurements taken of the A side of that channel at each site averaged together. This histograph can be used to evaluate the potential for the base receive side of the channel 283 for AIS operations throughout the entire VTS service area. The histographs for the base receive sides of channels 228 and 283 are shown below in Figures 2-5 and 2-6. Histographs for the base receive side of these channels were made only in distance mode. It is not anticipated that the base station receiver will operate in local mode.

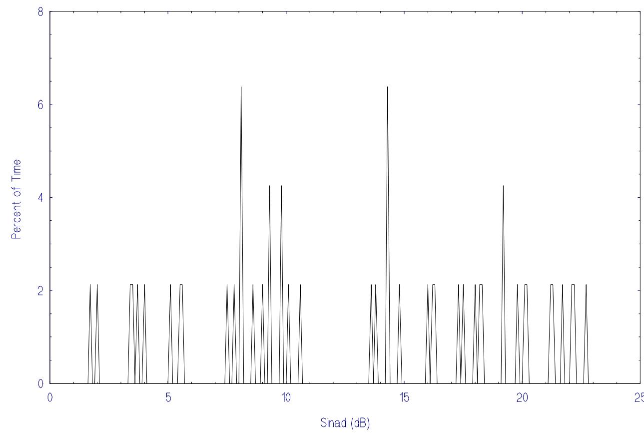

Figure 2-5
Channel 283 Base Receive Histograph

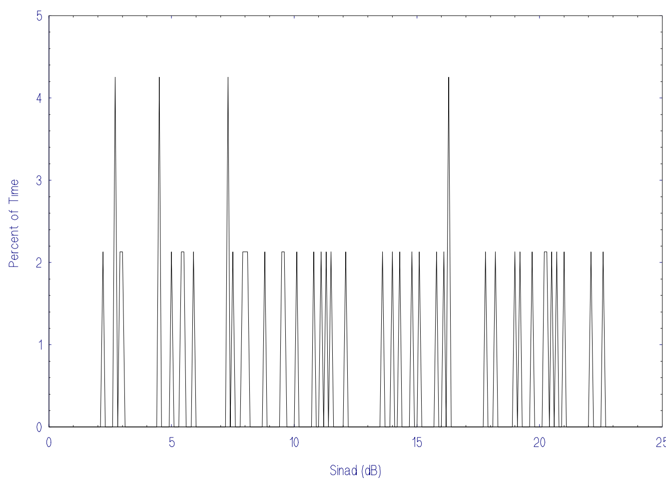

Figure 2-6
Channel 228 Base Receive Histograph

Figures 2-5 and 2-6 show that the A side of channels 283 and 228 should be further investigated for suitability as the link from the transponders to the base stations. The addition of crystal filters, which would be installed at each base station for each operational frequency, would give the base station receiver additional protection against adjacent tuned transmitters. The additional protection should shift the SINAD distribution to higher values for a greater percentage of time which would make the channel more attractive for AIS data ship-to-shore channel operations.

However it should be noted that this only applies to the interstitial channels. The crystal filters would not offer any protection against on-tune transmitters. Marine VHF radios, at this time, do not allow operators to tune to interstitial channels. Therefore, on-tune voice interference from marine VHF radios should not be a problem on this side of the data channel if it is operating on interstitial channels, unlike the channels that are currently being used.

2.1 Ship Receive SINAD Maps

SINAD maps for the ship receive side of the interstitial channels were produced based on the SINAD measurements taken on the river. A DGPS receiver was used to note the location of the vessel on the river when each SINAD measurement was made. By combining the ship's location and the SINAD measurement along with the channel designation, color coded maps of the B side of each interstitial channel were made. Each measurement point is a segment on the river. The maps can be used to evaluate the B side of each interstitial channels potential for use as the base station to transponder link for AIS operations. In addition, the maps can be used as a tool to predict possible interference for specific locations on the river and how well the receiver would operate in local and distance mode. The maps are color coded to represent SINAD levels as shown below in Table 2-1. Also included in the table is an estimation of the message throughput for that SINAD level. As Table 2-1 indicates, violet is the best color. Segments of the river that are colored violet should have above a 90 percent message throughput from the base station to the transponder for a ship operating in that part of the river.

Table 2-1

SINAD Value (dB)	Color	Message Throughput
0-3.9	red	not functional
4-7.9	yellow	#30 %
8-11.9	green	#70 %
12-15.9	blue	#80 %
<16	violet	$90 %

SINAD maps for the ship receive sides of channels 228 and 283 for the receiver operating in local and distance modes are shown in Appendix B. The map for the receiver operating in distance mode on channel 228 (see pages B-2 to B-4) shows that many segments of the river are colored blue and green near New Orleans and Baton Rouge with one yellow segment near downtown Baton Rouge. This indicates that the receiver was experiencing a moderate amount of interference in the New Orleans and Baton Rouge areas on channel 228 in those segments of the river while it was operating in distance mode. This interference may cause the AIS transponder only to receive about 70 percent of the base station commands and other ships broadcasts if it were operating on that channel in those sections of the river. The map also shows that the river has mostly violet colored segments down river from New Orleans which indicates that the interference is significantly less in those segments of the river and that the transponder should receive almost all of the base station commands. With the receiver set to local mode for channel 228 (see pages B-5 to B-7), all but two segments of the river are colored violet. This indicates that if the AIS transponder were operated in local mode while using channel 228 that the interference should not affect its ability to receive base station commands and re-broadcasted ships position reports through the entire VTS service area.

The map for the receiver operating in distance mode on channel 283 (see pages B-8 to B-10) shows that most of the segments of the river are colored blue near New Orleans and Baton Rouge with mostly violet segments past New Orleans. There are a few green segments in the New Orleans and Baton Rouge areas. This indicates that the receiver was experiencing some interference in the New Orleans and Baton Rouge areas on channel 283 in those segments of the river. The interference may cause the AIS transponder to miss a few of the base station commands and re-broadcasted ship's position data.

The map for channel 283 in distance mode also shows that the river has mostly violet colored segments down river from New Orleans with one green segment near Pilot town. This indicates that the interference should not cause the transponder to miss receiving base station commands and ships position reports in those segments of the river. With the receiver set to local mode for channel 283 (see pages B-11 to B-13), all but two segments of the river are colored violet. Those two segments are colored gray meaning that no measured data was collected for those segments. This indicates that if the AIS transponder were operated in local mode while using channel 283 that the interference should not affect its ability to receive base station commands and re-broadcasted ships position reports through the entire VTS service area.

Overall, for the receiver operating in distance mode, channel 283 shows better promise for AIS operations. It has more segments of the river colored violet than channel 228 which indicates that the interference has less of an effect on that channel. In local mode operation, the two channels are equal with respect to possible use as AIS data channels. Both channels show violet segments of the river from Baton Rouge to the sea buoy indicating that the interference should not affect base station to transponder communications. However, operation of the transponders in local mode assumes that the base station transmitters have sufficient signal coverage for a high message throughput.

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SECTION 3
CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn based on the results of these tests:

1. Histographs of the ship receive sides of the interstitial channels between the public correspondence channels show a high distribution of SINAD values above 16 dB, which indicates that the B sides of the interstitial channels have the potential for use as AIS data channels for shore-to-ship communications in the lower Mississippi River vessel traffic service area.

2. The distribution of the SINAD measurements for the ship receive interstitial channel histographs was greatest when the receiver was operated in local mode.

3. Histographs of the base receive sides of the interstitial channels between the public correspondence channels show some SINAD distributions above 16 dB. These results indicate that, pending additional testing with crystal filters, the A sides of the interstitial channels have the potential for use as AIS data channels for ship-to-shore communications in the lower Mississippi River vessel traffic service area.

4. SINAD maps of the ship receive side of the interstitial channels 228 and 283 shows that if the transponder is operated in distance mode while using those channels, that RF interference in the New Orleans and Baton Rouge areas of the river may reduce the ability of the transponder to receive base station commands, text messages, and other transponders relayed position reports. This interference would have the same effect if the transponder were using the interstitial channels between the public correspondence channels as well.

5. SINAD maps of the ship receive side of the interstitial channels 228 and 283 shows that if the transponder is operated in local mode while using those channels, that the RF interference to transponders in the New Orleans and Baton Rouge areas of the river should be greatly reduced. This would also apply if the transponder were using the interstitial channels between the public correspondence channels as well.

NTIA recommends that when the Coast Guard chooses duplex AIS data channels they:

1. Develop a strategy for planning and coordinating the use of the interstitial channels, located between the public coast station channels, for AIS data channels with the auction winners in each district that the Coast Guard intends to operate a VTS.

2. Select candidates for AIS data channels that could be dedicated to AIS operations and not be shared with any other types of services or functions, so that the VTS system operates with a minimal amount of RF interference and its safety and reliability is enhanced.

3. Further investigate the interstitial channels potential for use as AIS data channels in the lower Mississippi River vessel traffic service area through additional testing with crystal filters (tuned to the appropriate channels) installed at the base stations before the operational channels are chosen.

4. Choose AIS data channels and a re-use plan that limits the exposure of the transponder receiver to NOAA VHF weather broadcasts in Baton Rouge, New Orleans, and Buras. Transponders used in those sectors of the VTSA should be operated on channels that have the greatest frequency separation between the NOAA weather broadcasts and the shore-to-ship side of the data channel.

5. Operate the AIS transponder receiver in local mode at all times, if there is sufficient desired signal coverage.

Appendix A
Ship Receive Interstitial Channel
SINAD Histographs

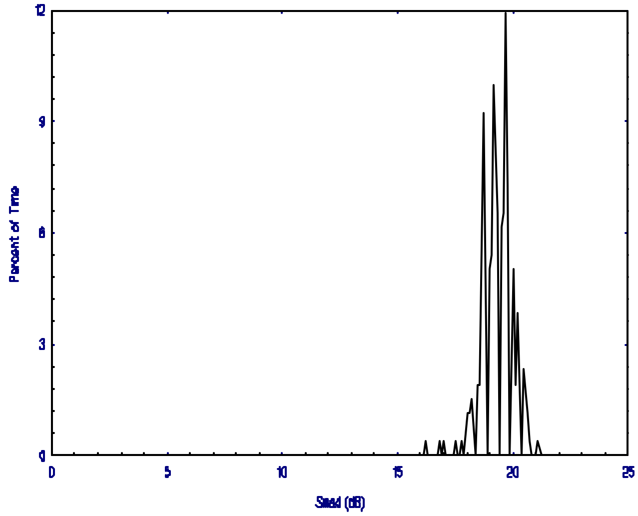


Figure A-1
Channel 283 Local Mode

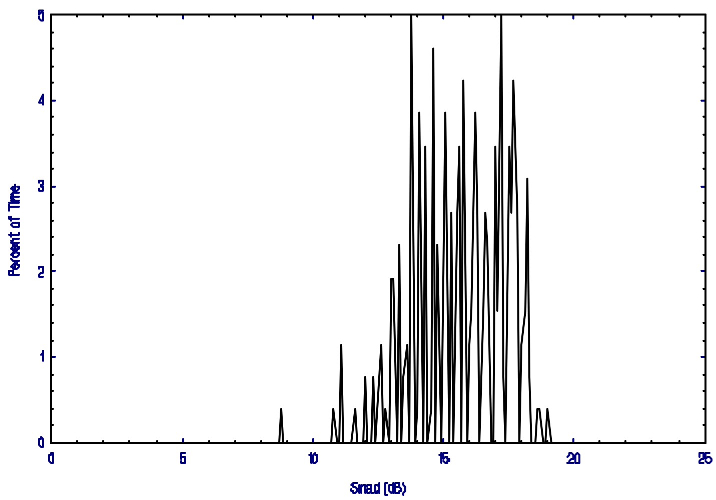


Figure A-2
Channel 283 Distance Mode

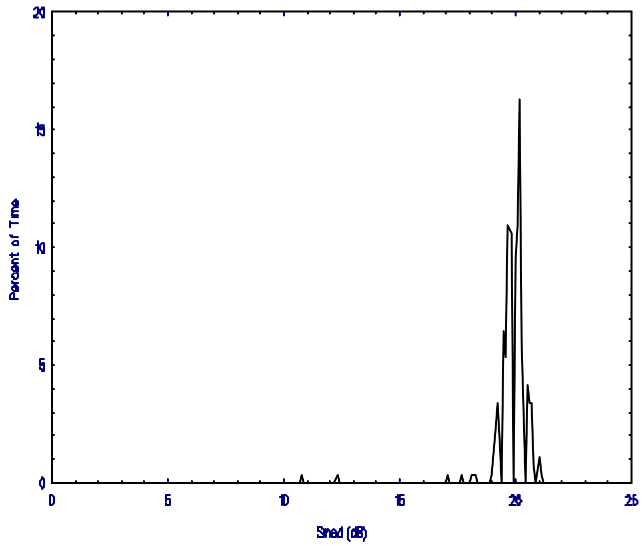


Figure A-3
Channel 224 Local Mode

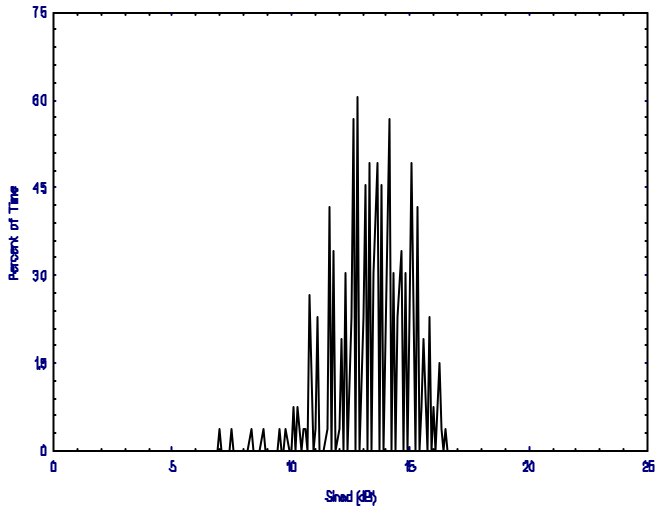


Figure A-4
Channel 224 Distance Mode

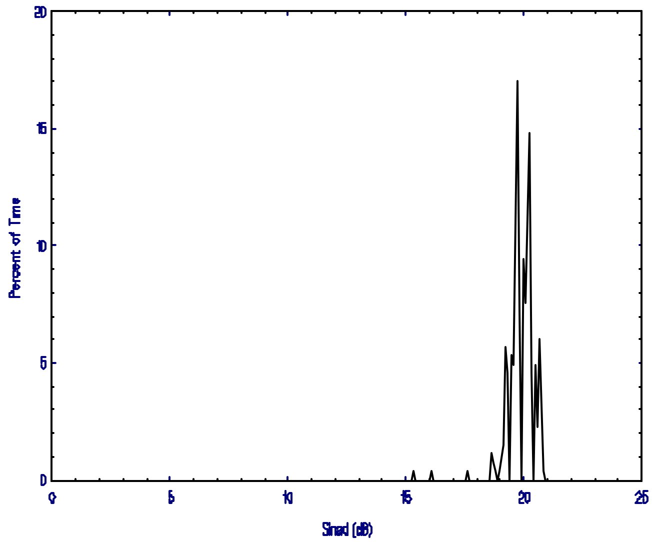


Figure A-5
Channel 284 Local Mode

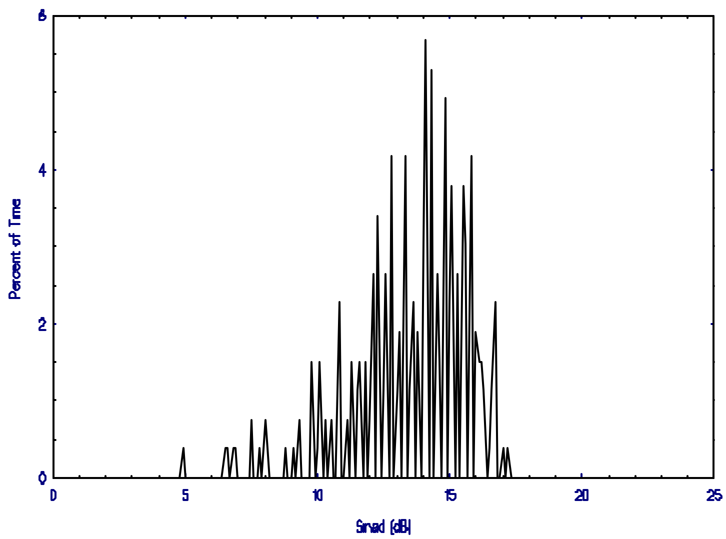


Figure A-6
Channel 284 Distance Mode

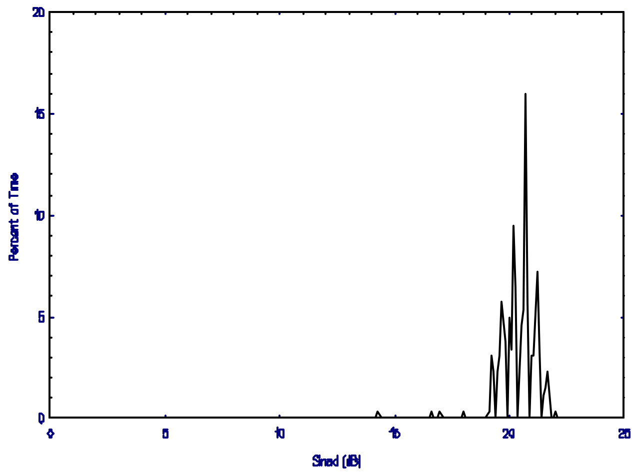


Figure A-7
Channel 225 Local Mode

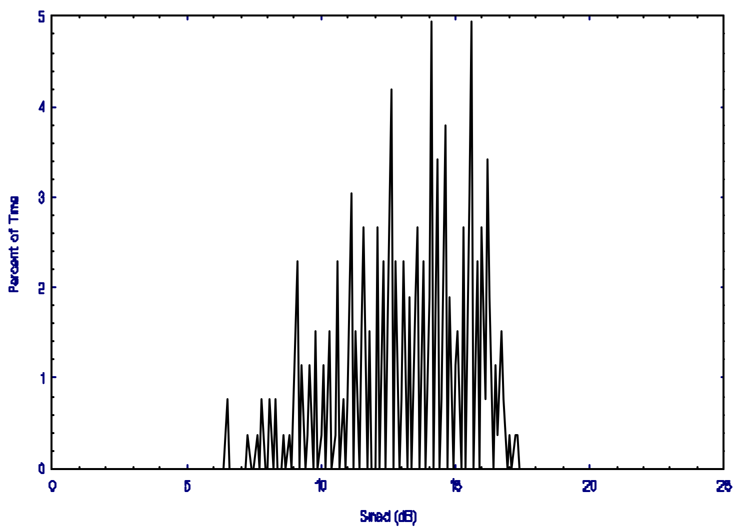


Figure A-8
Channel 225 Distance Mode

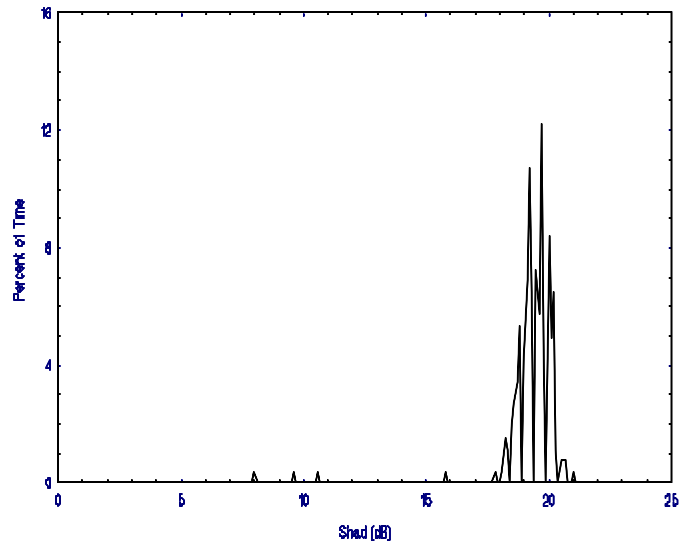


Figure A-9
Channel 285 Local Mode

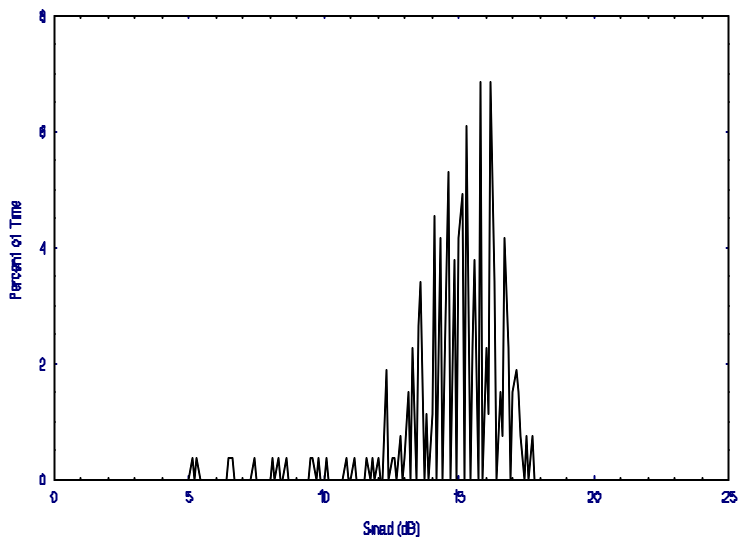


Figure A-10
Channel 285 Distance Mode

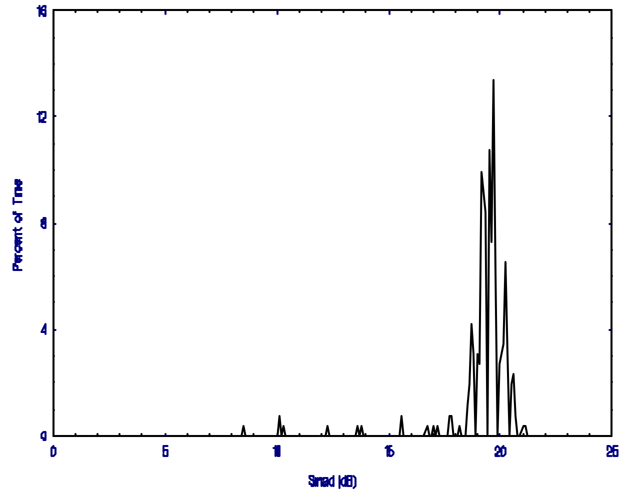


Figure A-11
Channel 226 Local Mode

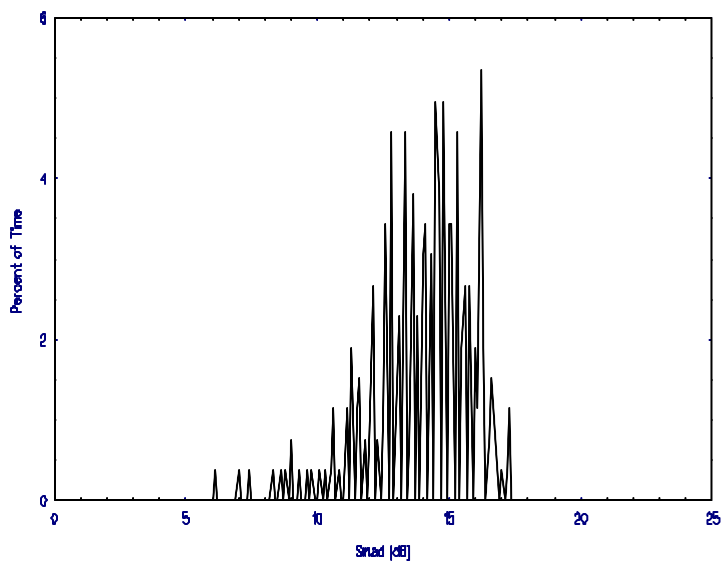


Figure A-12
Channel 226 Distance Mode

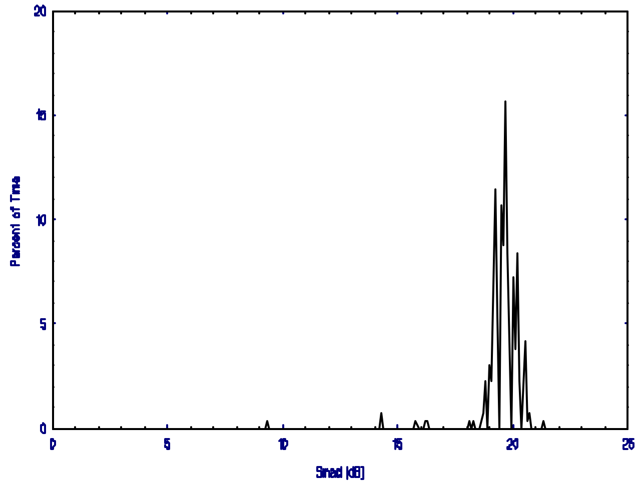


Figure A-13
Channel 286 Local Mode

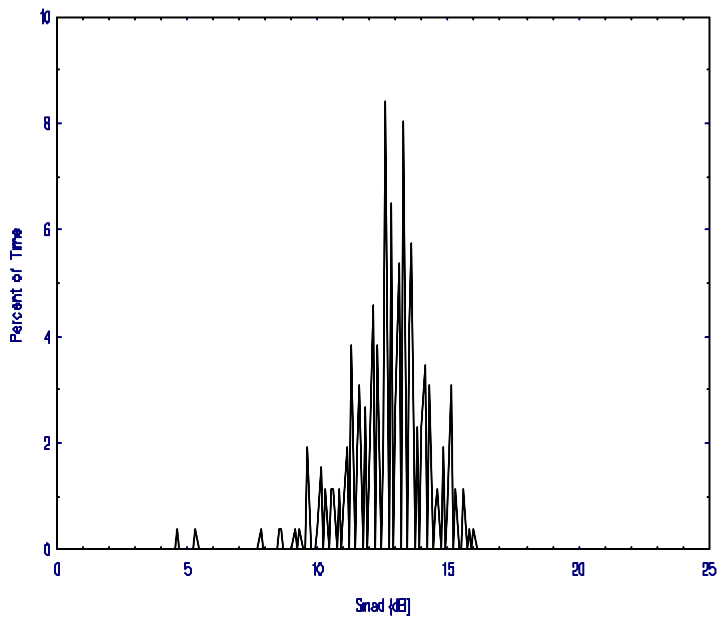


Figure A-14
Channel 286 Distance Mode

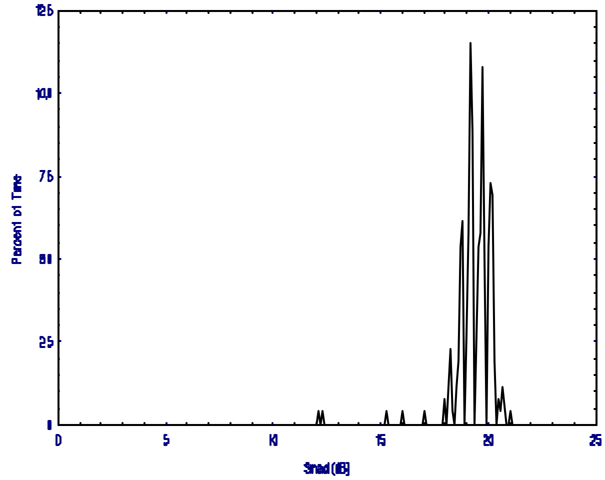


Figure A-15
Channel 227 Local Mode

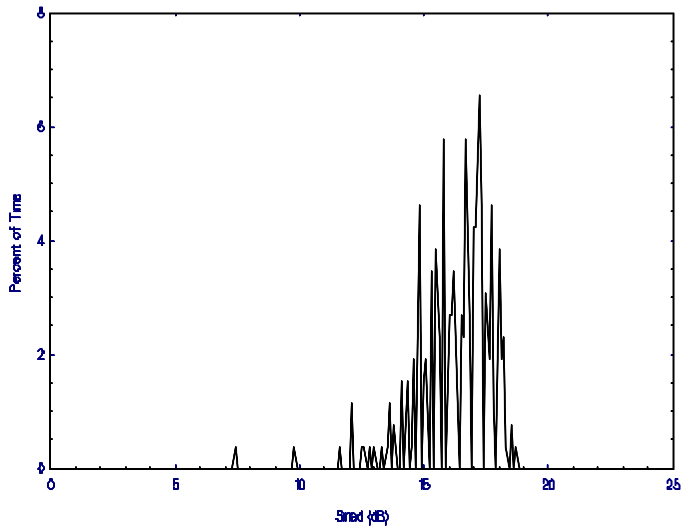


Figure A-16
Channel 227 Distance Mode

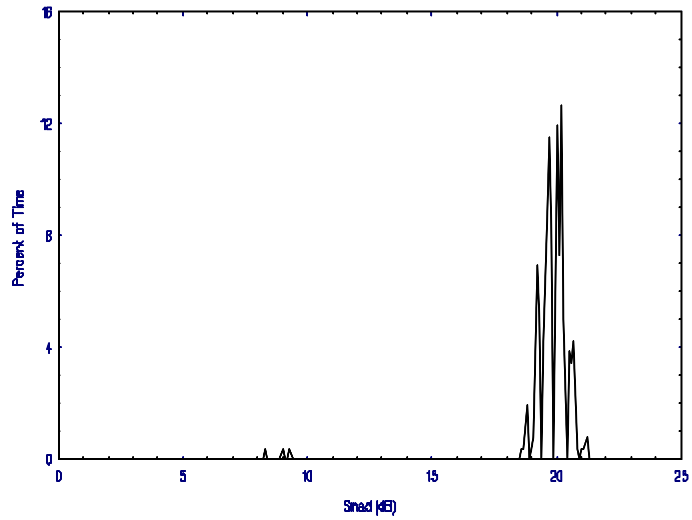


Figure A-17
Channel 287 Local Mode

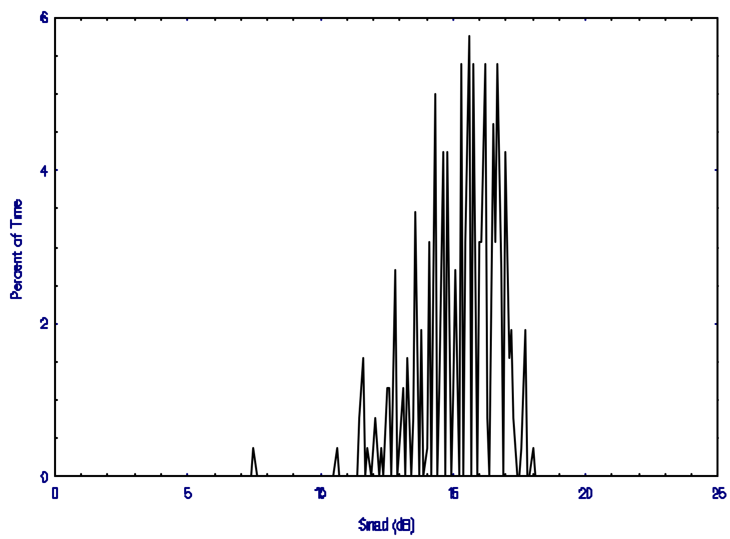


Figure A-18
Channel 287 Distance Mode

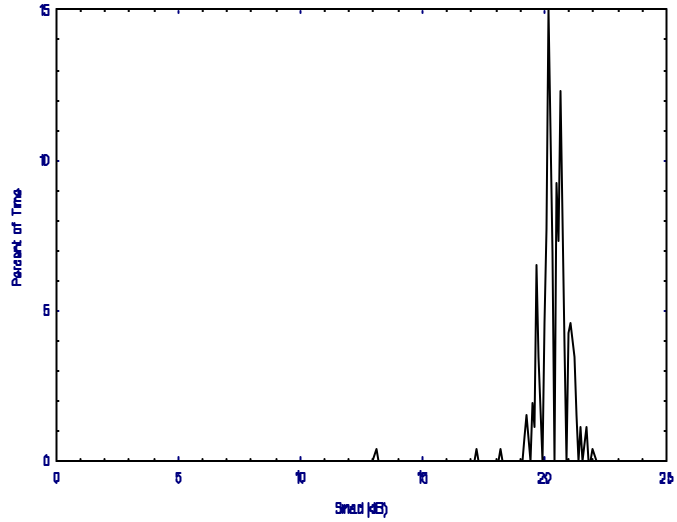


Figure A-19
Channel 228 Local Mode

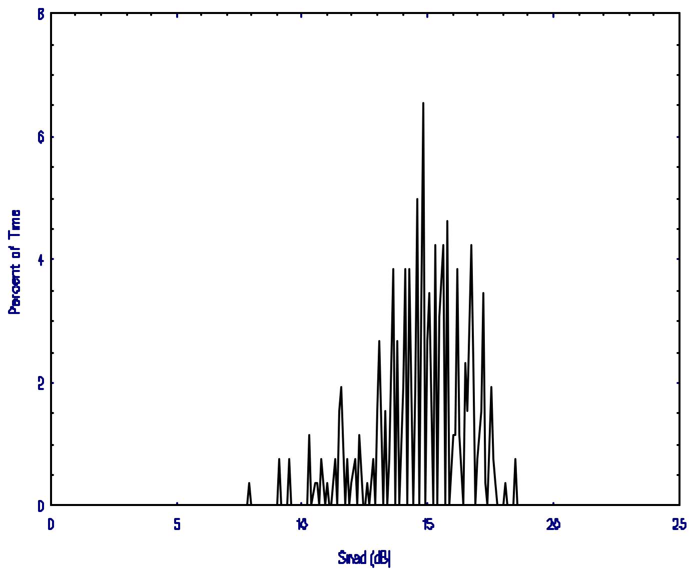


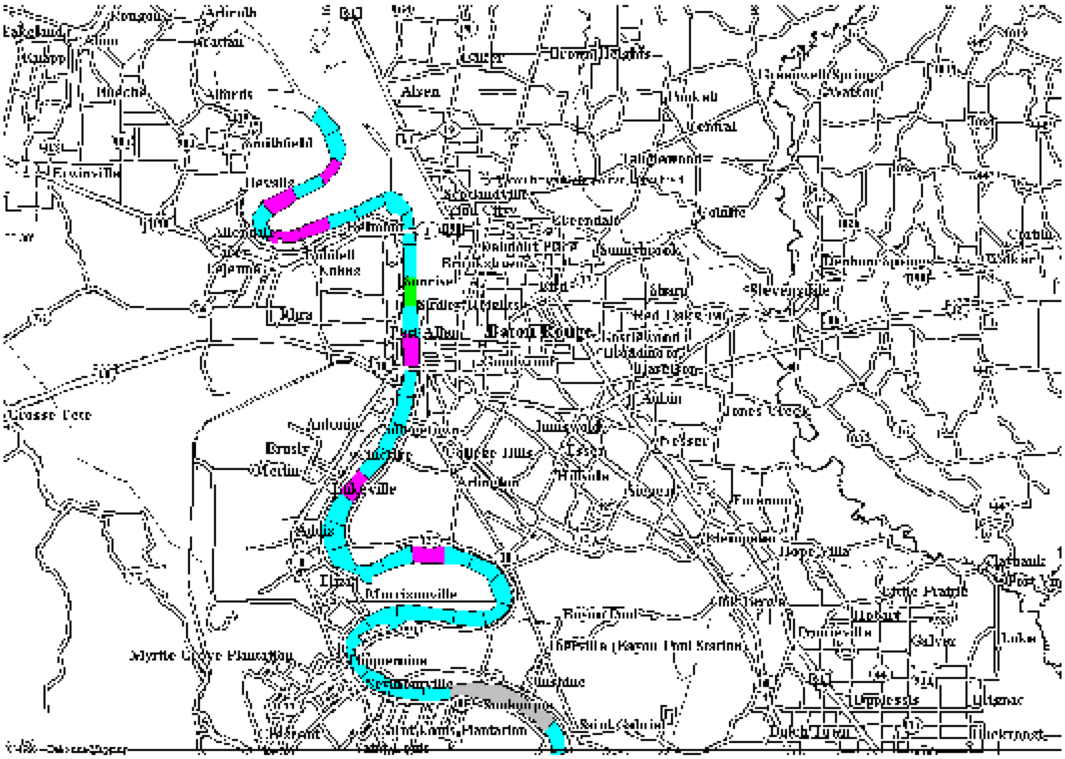
Figure A-20
Channel 228 Distance Mode

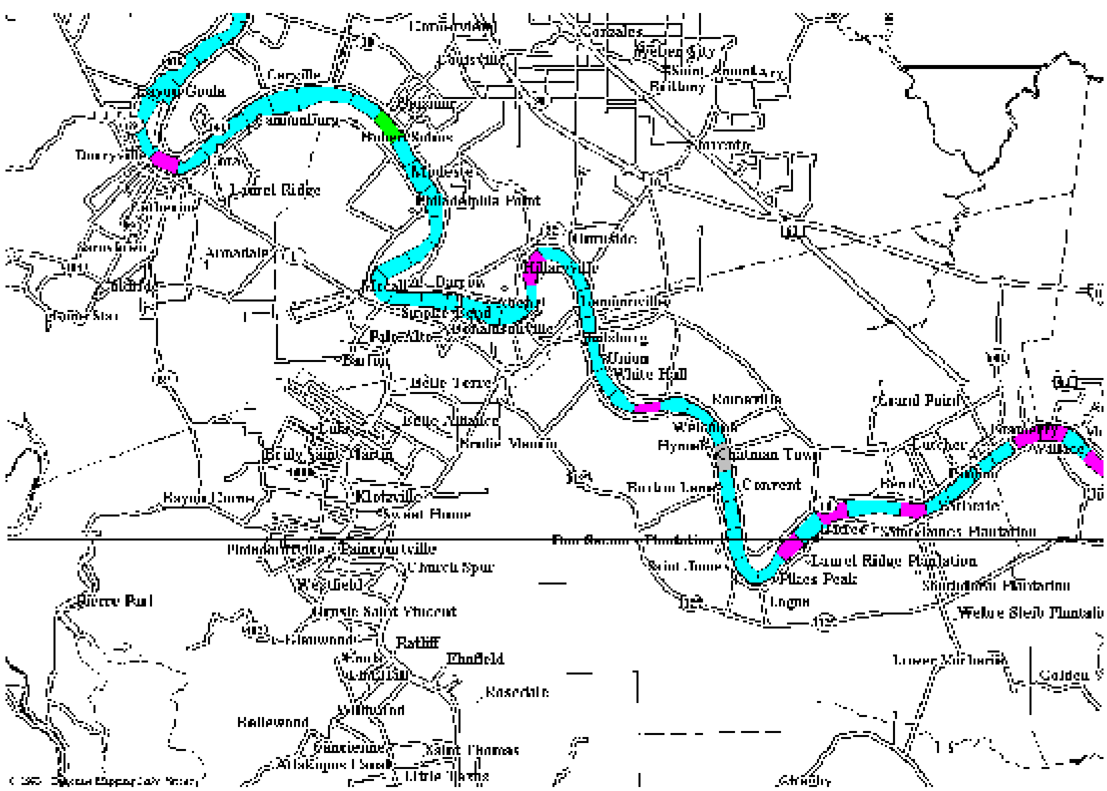
Appendix B
Ship Receive SINAD Maps

Each color corresponds to a SINAD value for that segment of the river.

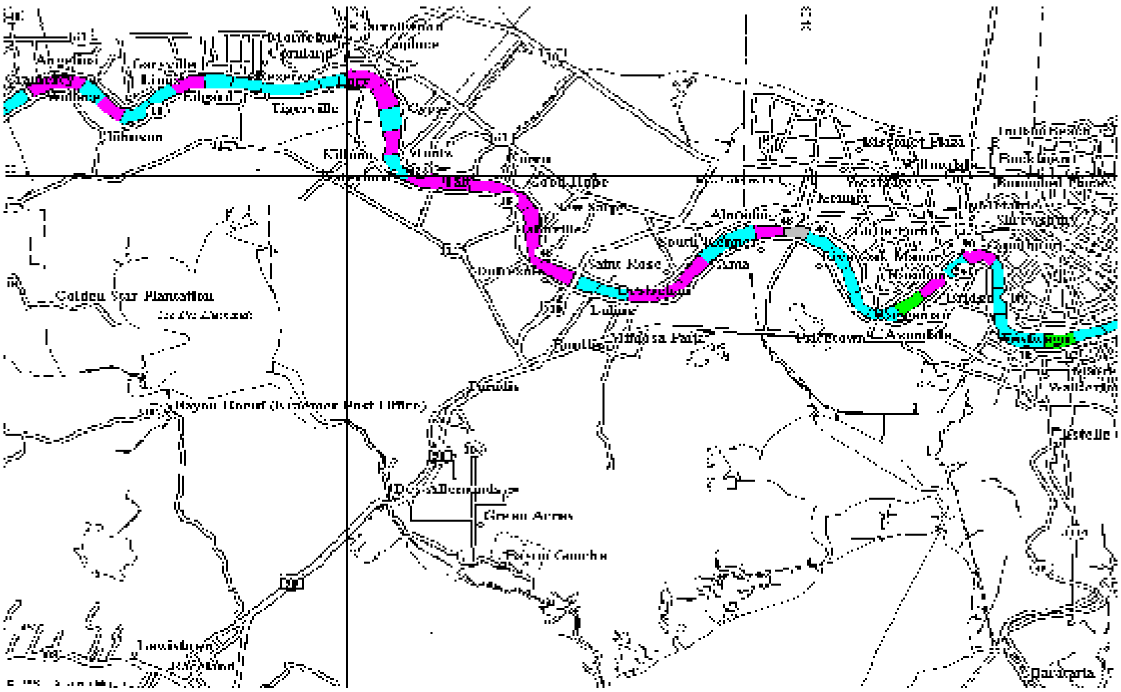
00 - 03.9 dB
04 - 07.9 dB
08 - 11.9 dB
12 - 15.9 dB
16 - > dB
NO DATA

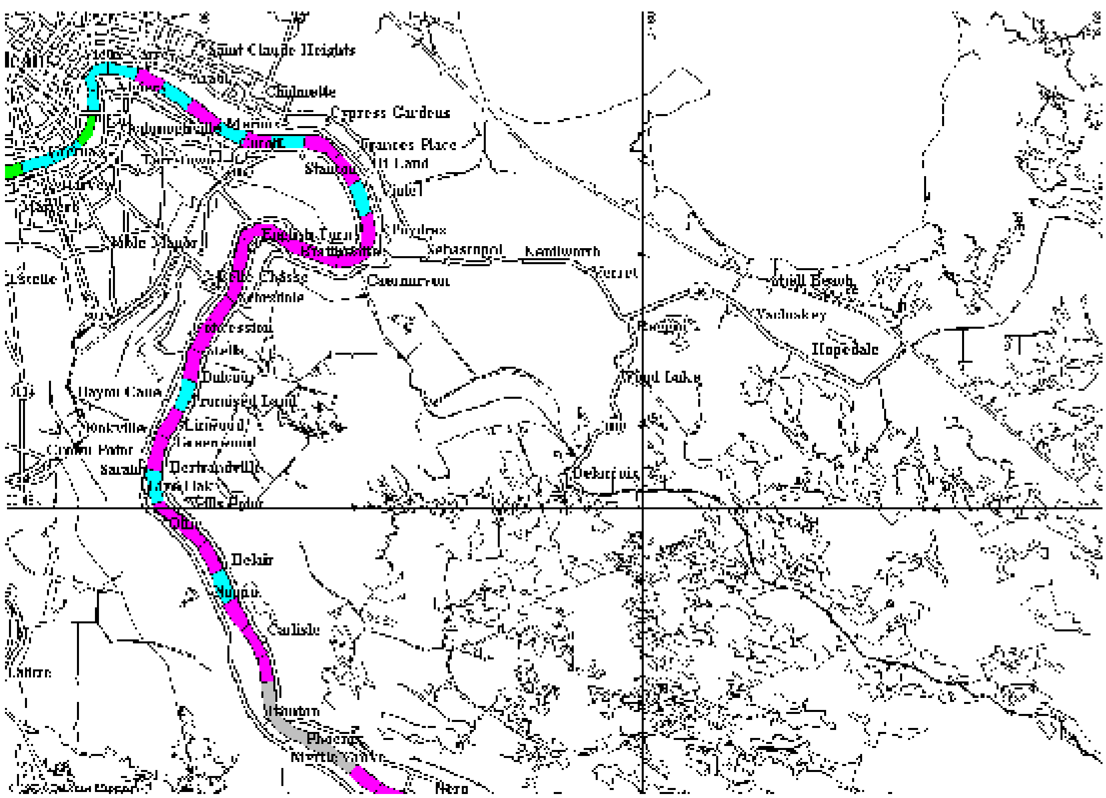
Channel 228 Ship Receive Distance Mode



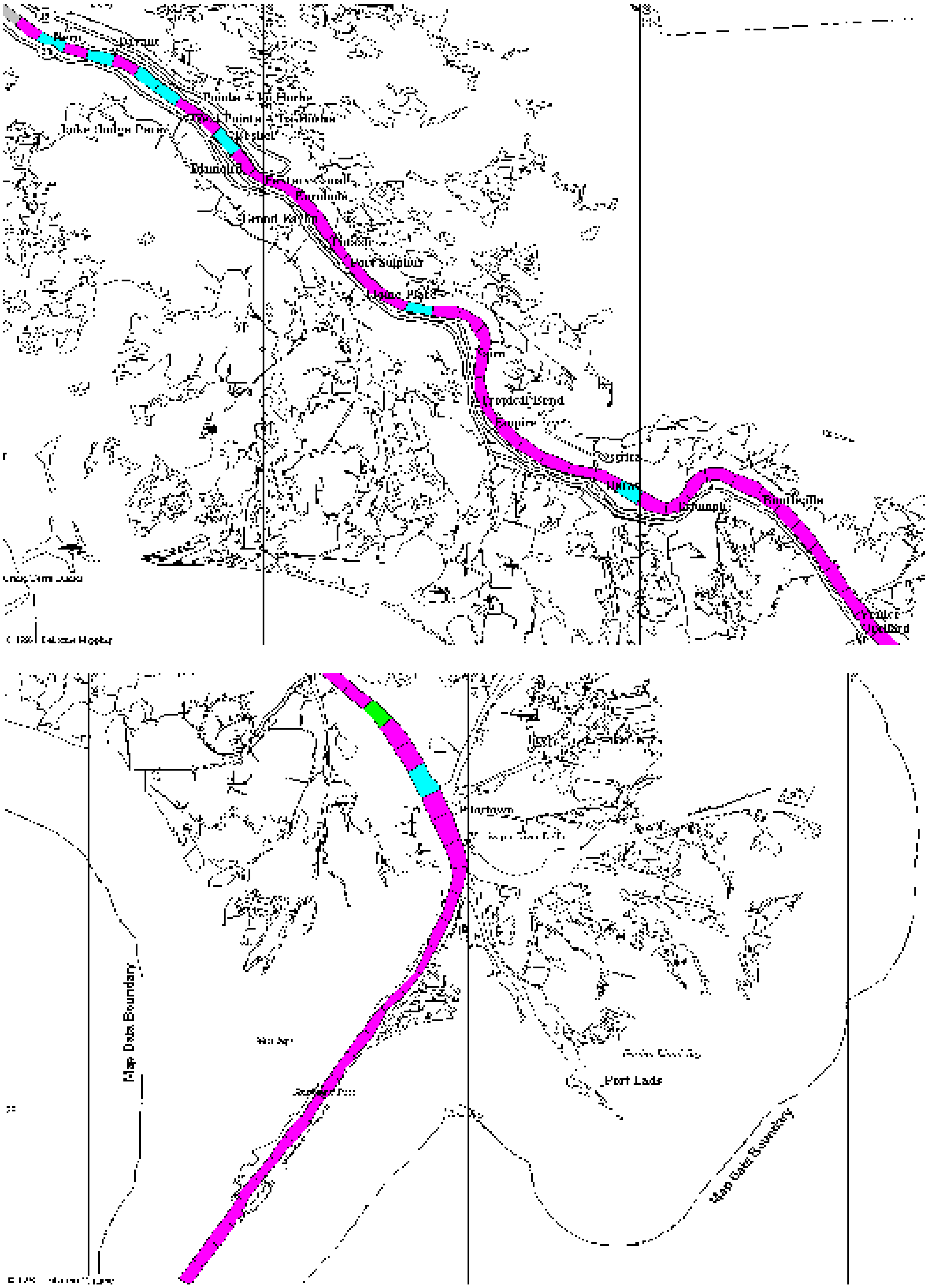


Channel 228 Ship Receive Distance Mode

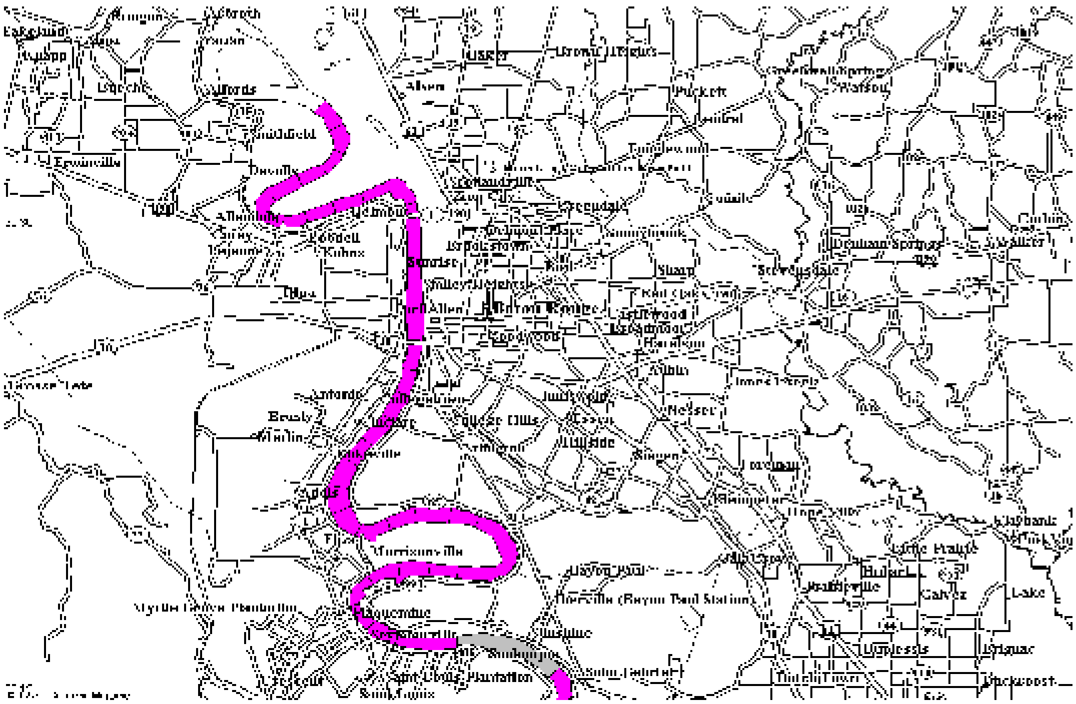


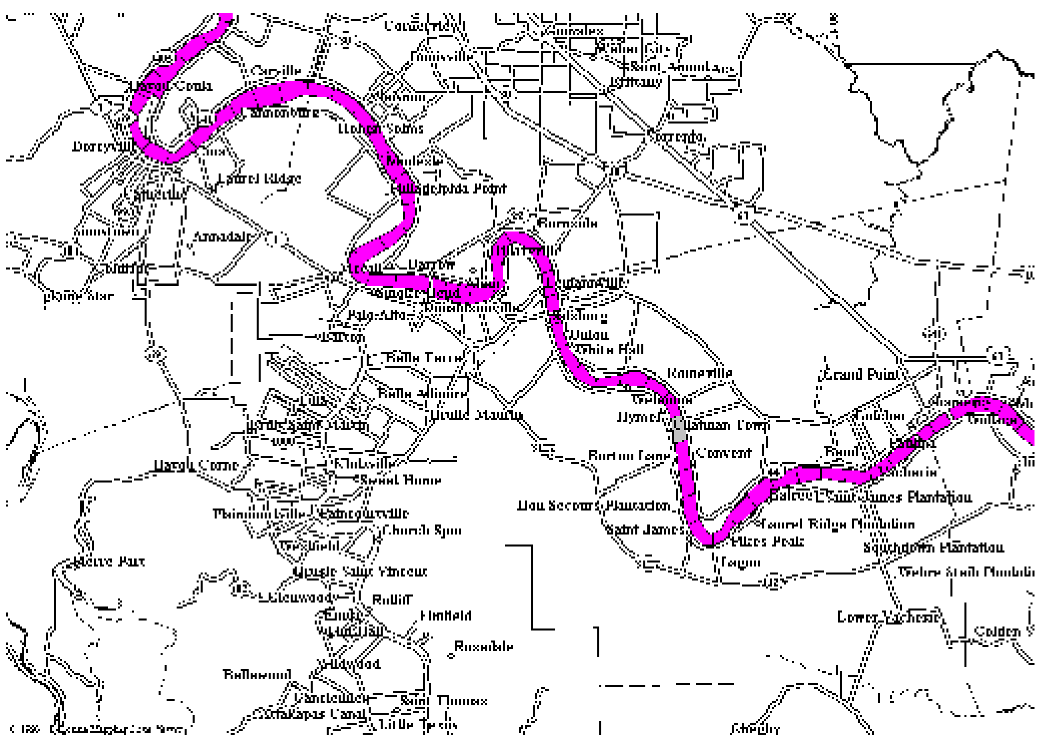


Channel 228 Ship Receive Distance Mode

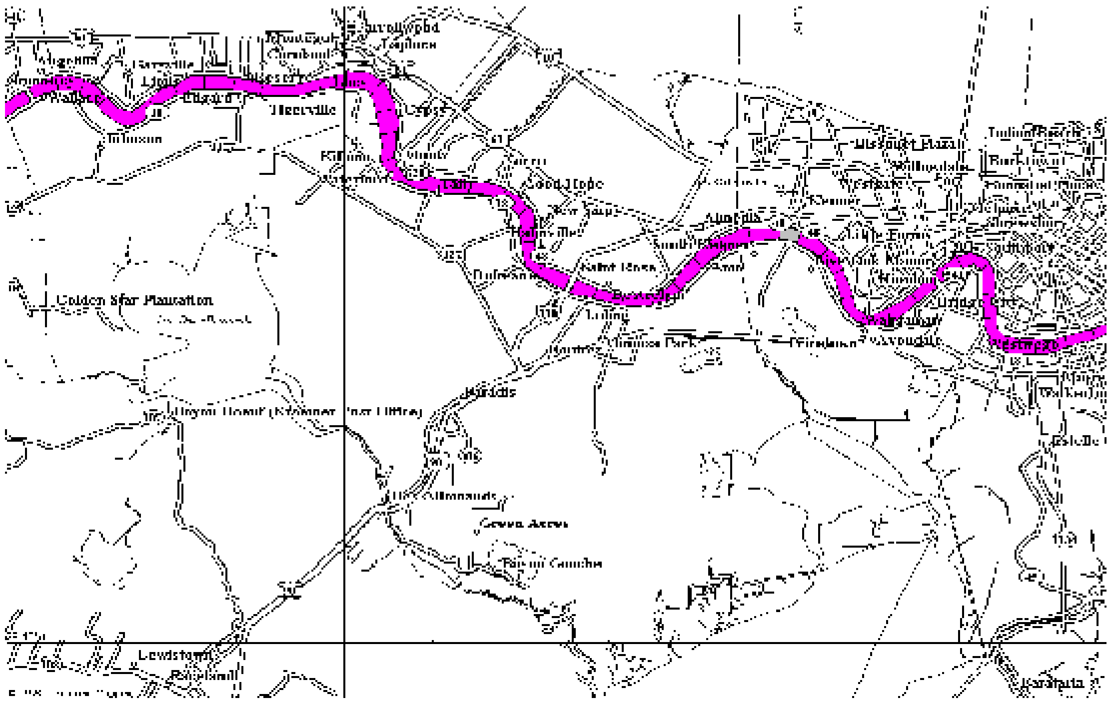


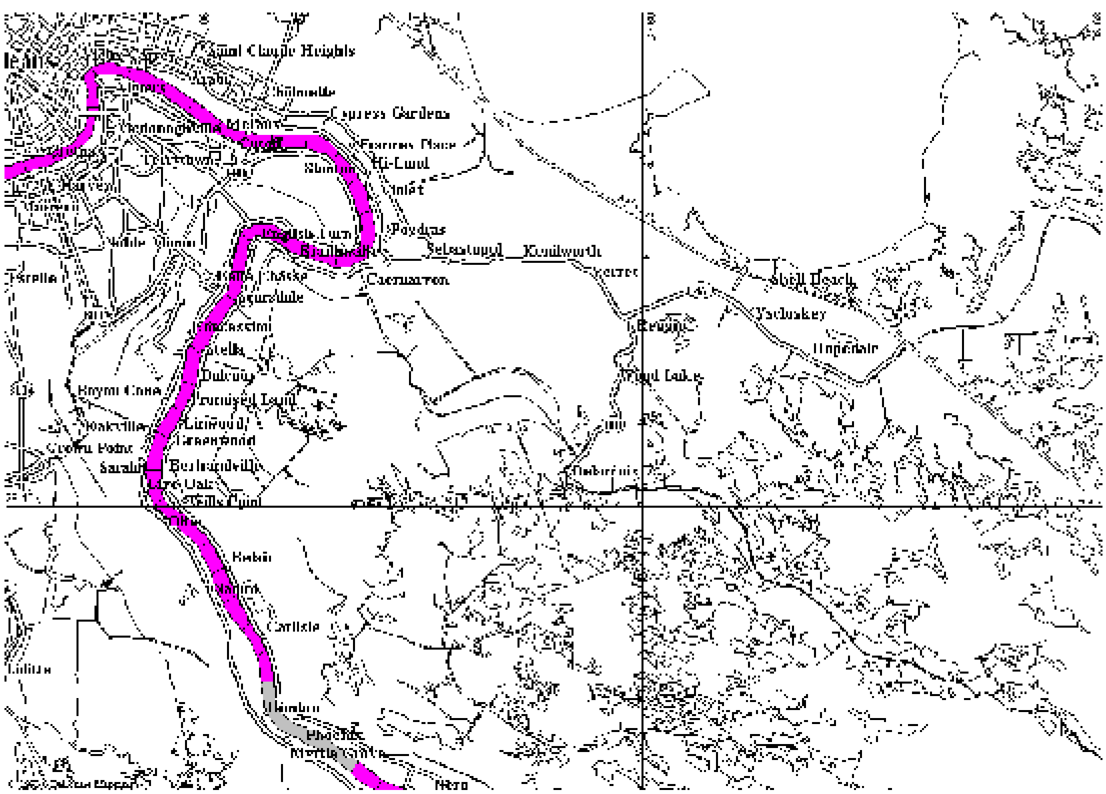
Channel 228 Ship Receive local Mode



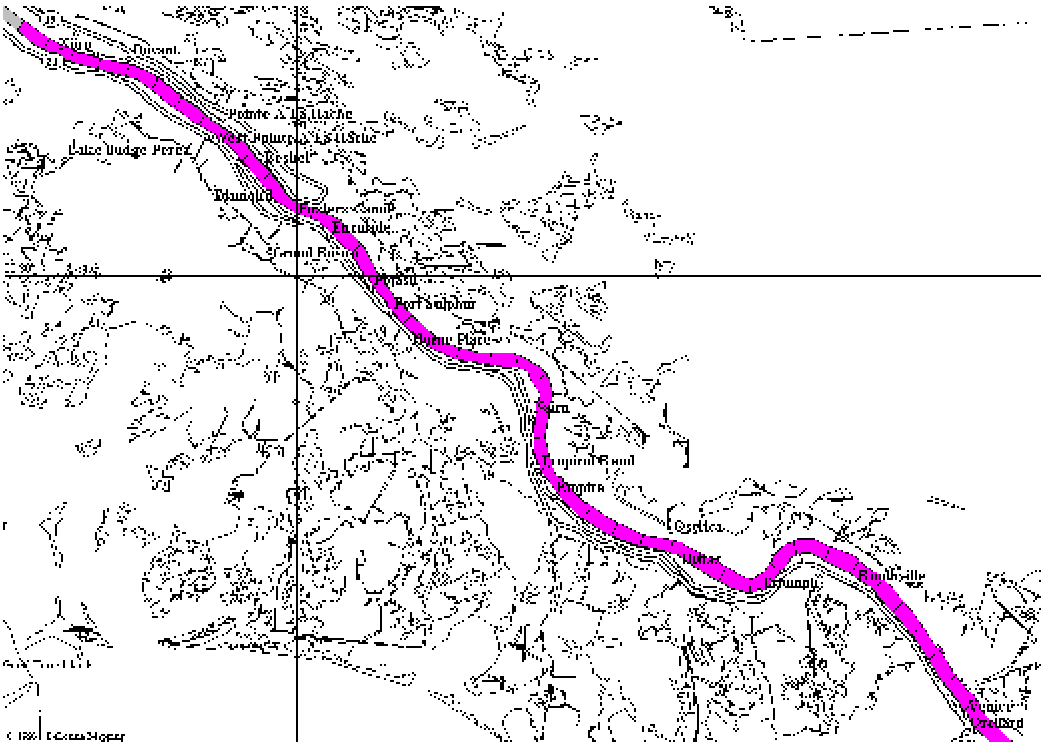


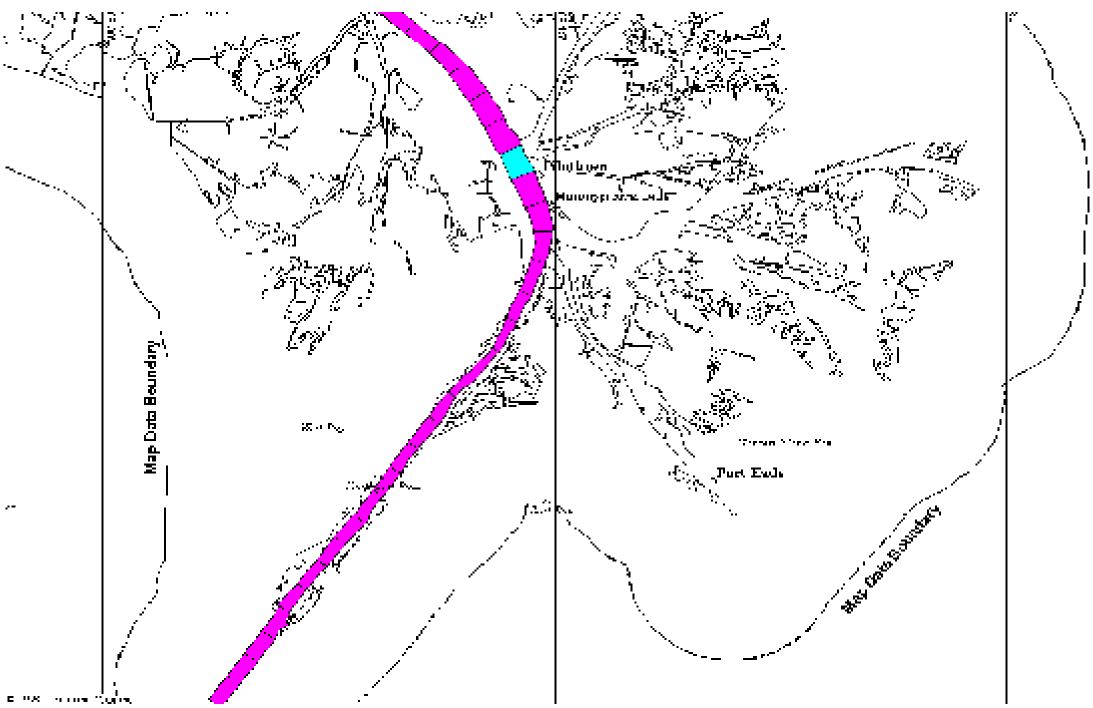
Channel 228 Ship Receive local Mode



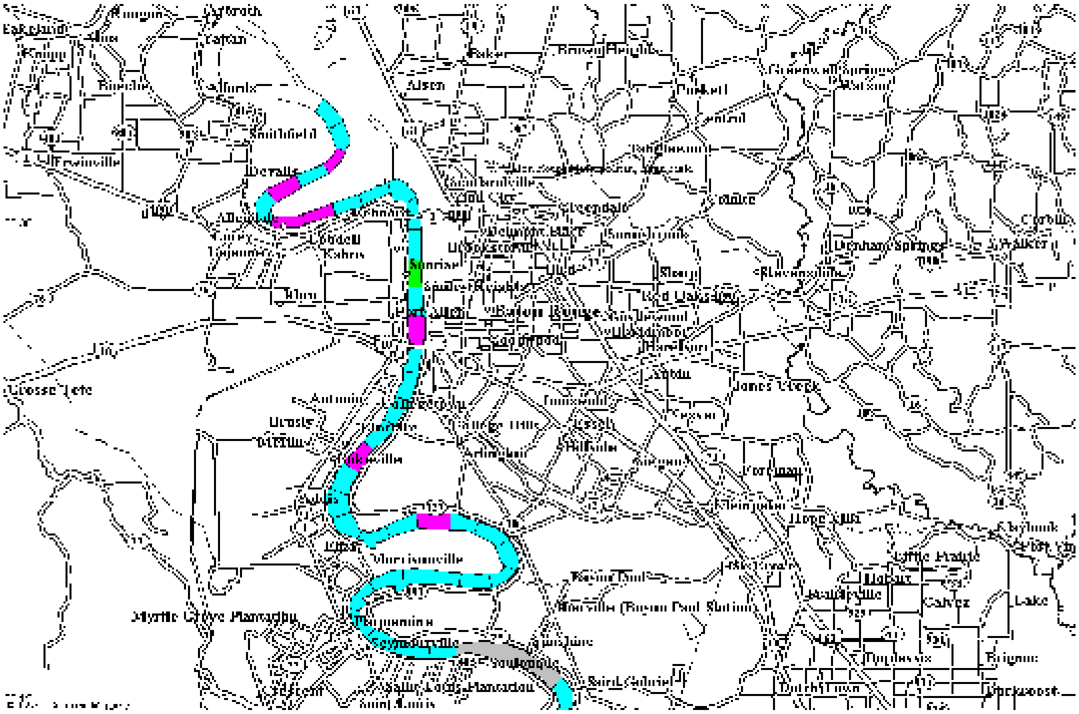


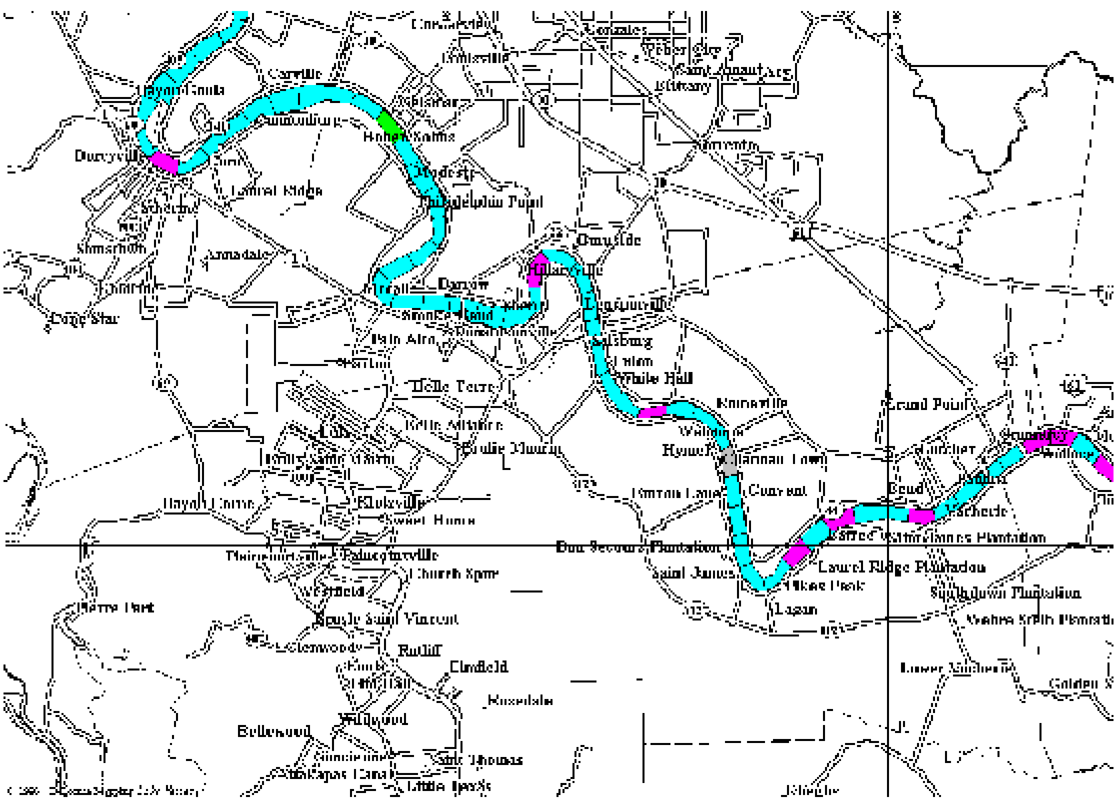
Channel 228 Ship Receive local Mode



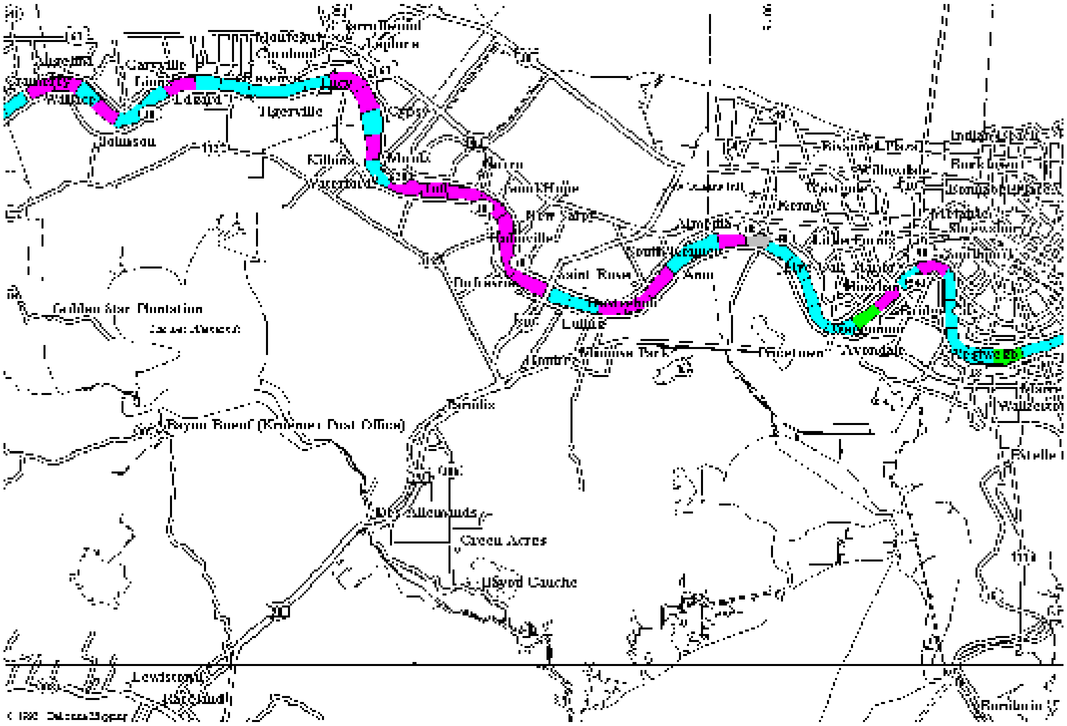


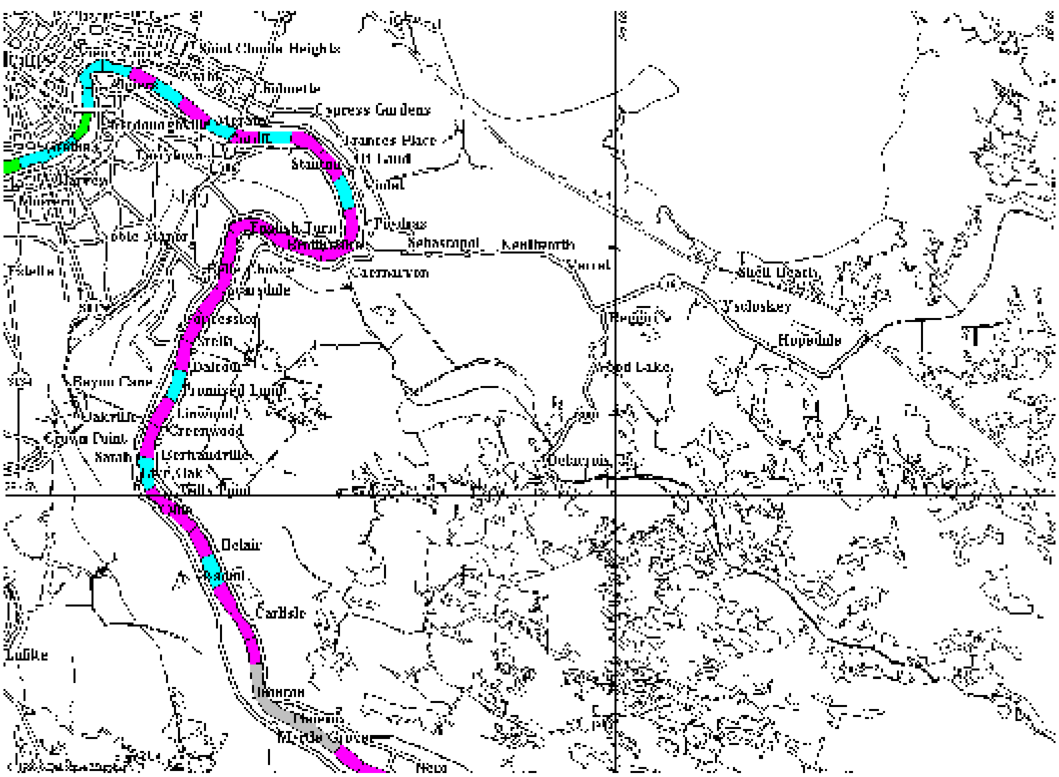
Channel 283 Ship Receive Distance Mode



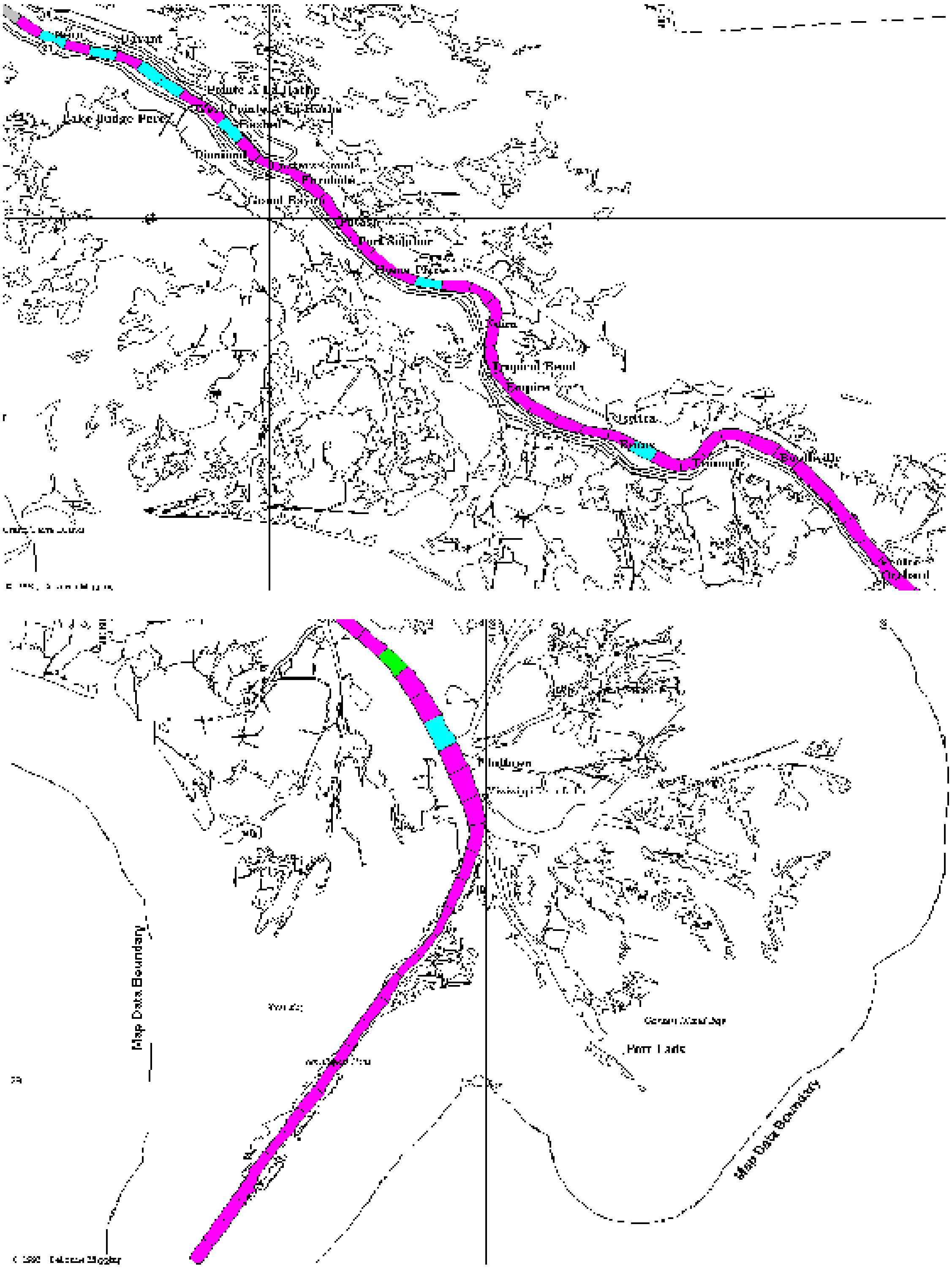


Channel 283 Ship Receive Distance Mode

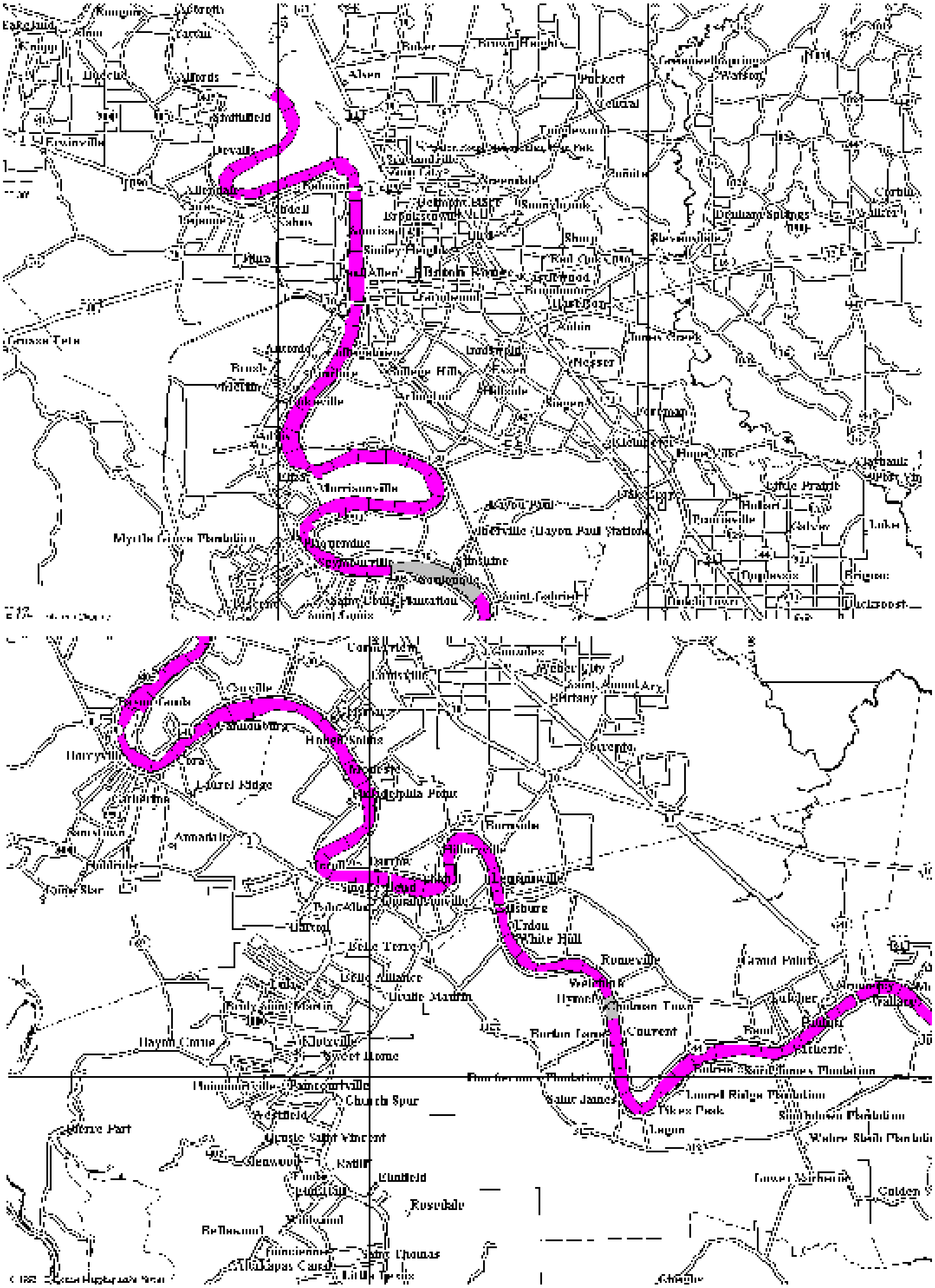




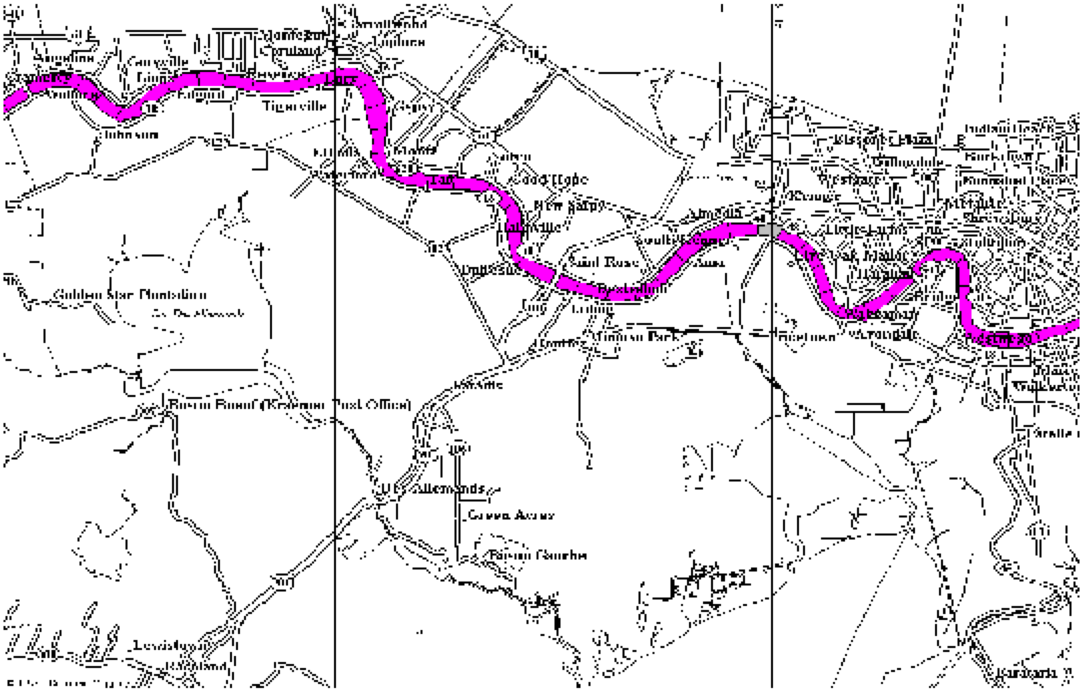
Channel 283 Ship Receive Distance Mode

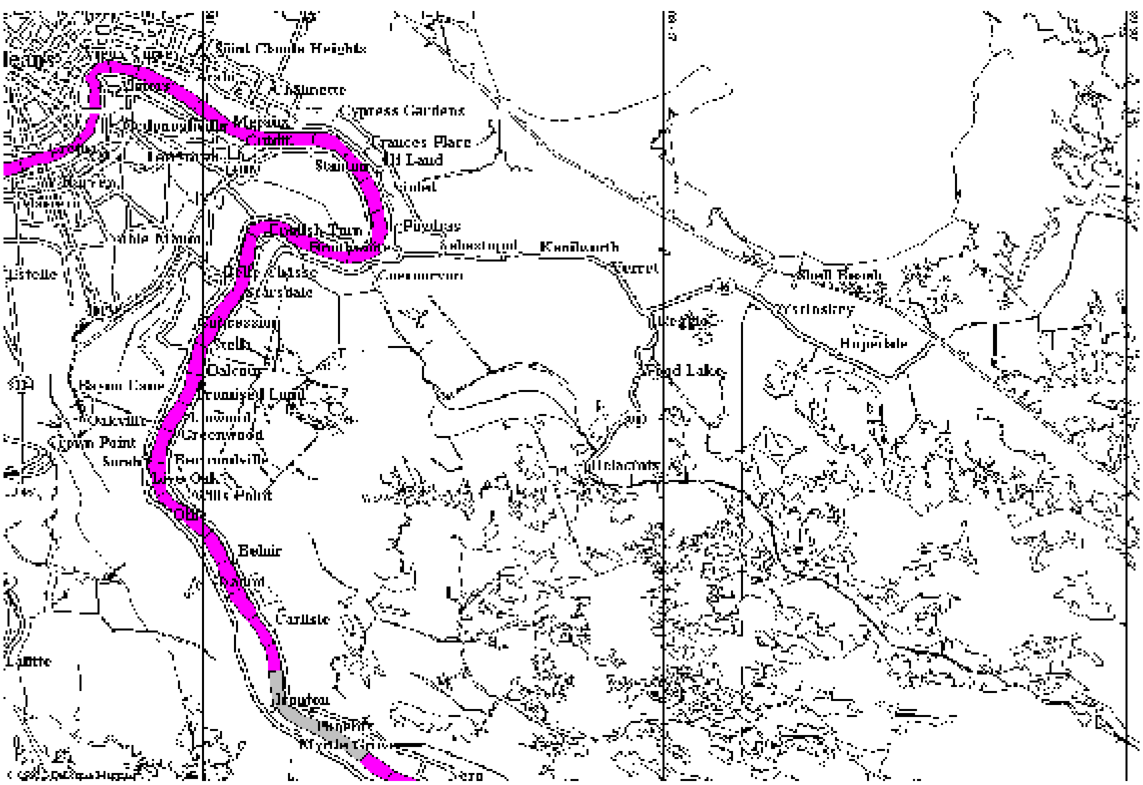


Channel 283 Ship Receive Local Mode

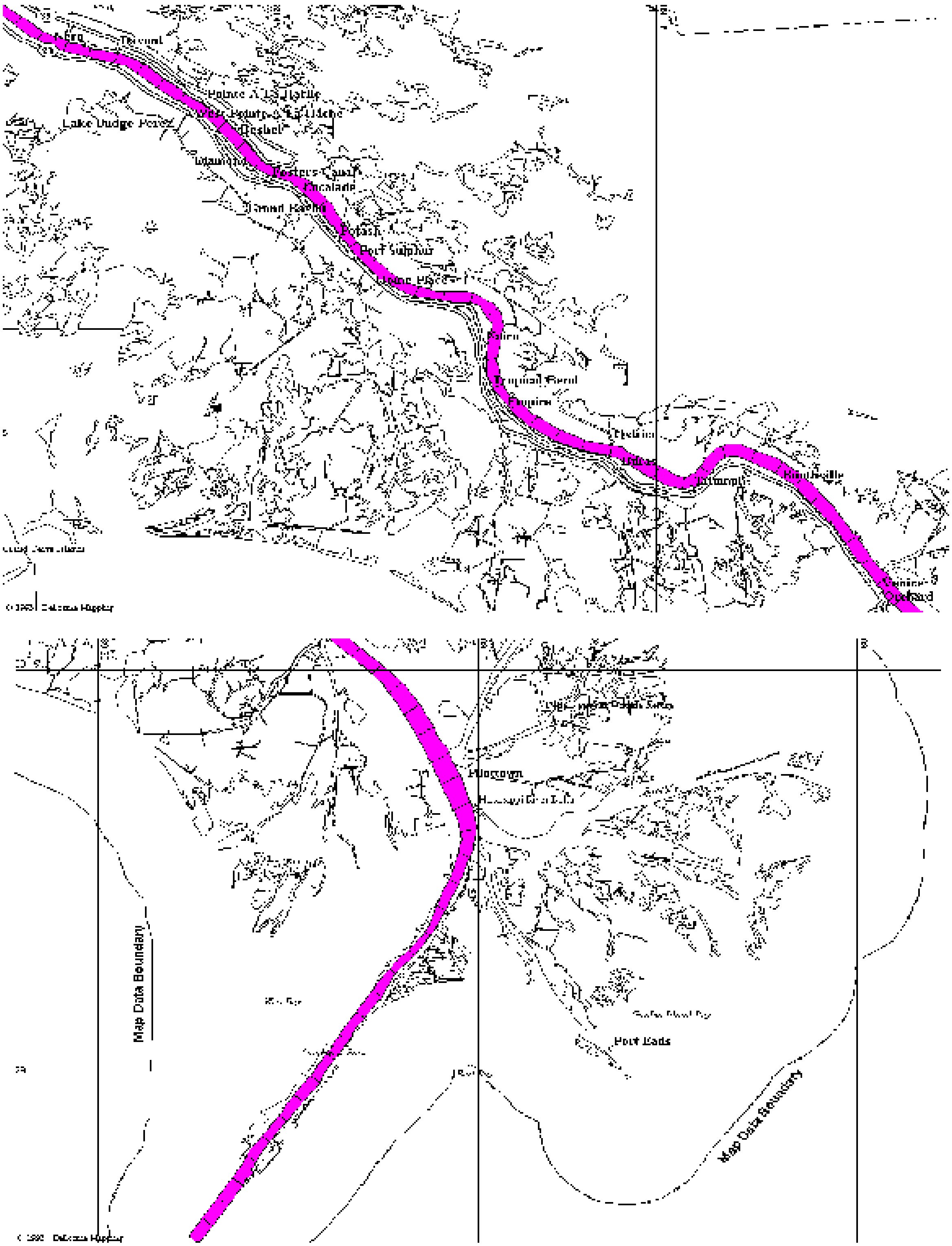


Channel 283 Ship Receive Local Mode





Channel 283 Ship Receive Local Mode



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Appendix C
Base Receive Interstitial Channel
SINAD Histographs

The Histographs for the base receive interstitial channels are based on the combined measurements at each communication high site.

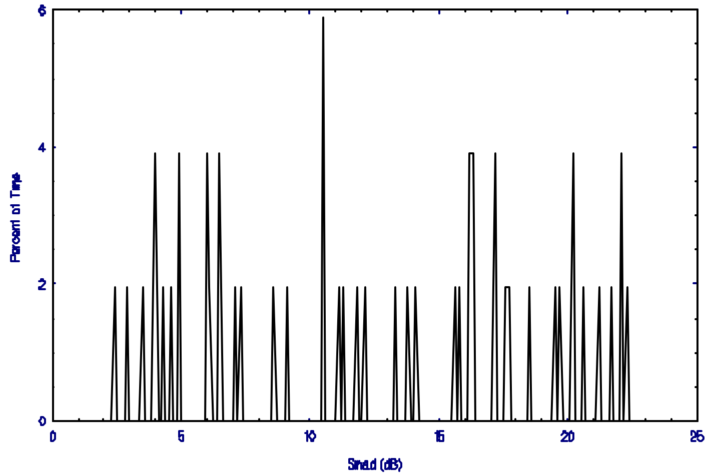

Figure C-1
Channel 224 Base Receive

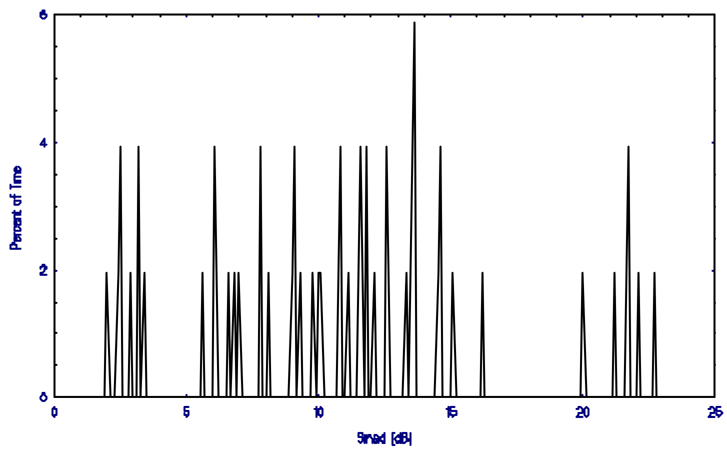

Figure C-2
Channel 284 Base Receive

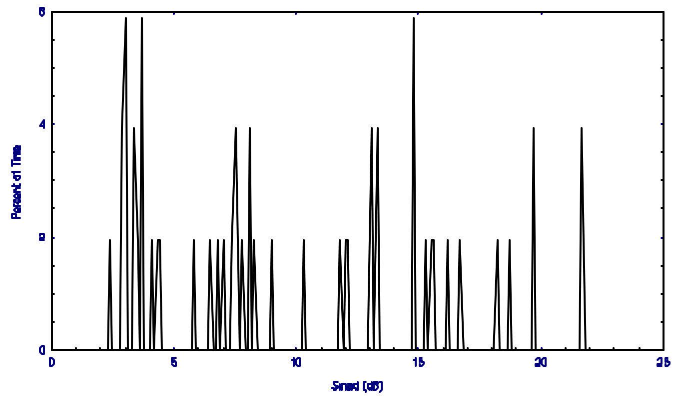

Figure C-3
Channel 225 Base Receive

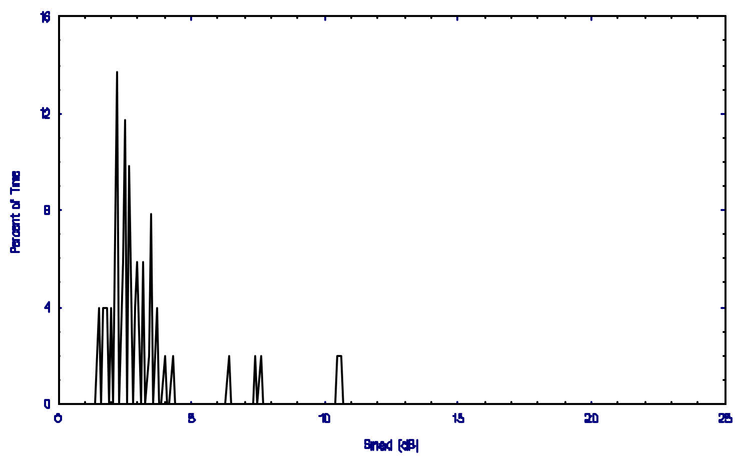

Figure C-4
Channel 285 Base Receive

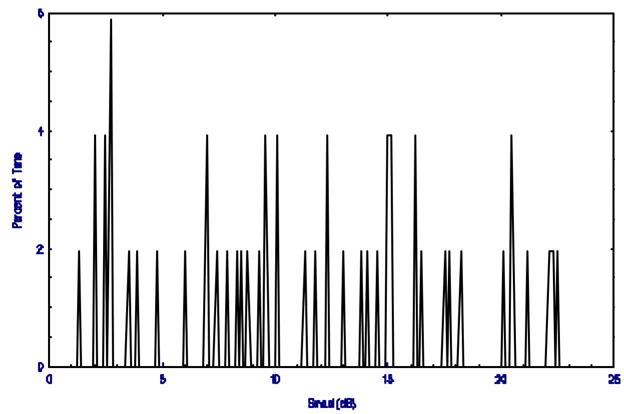

Figure C-5
Channel 226 Base Receive

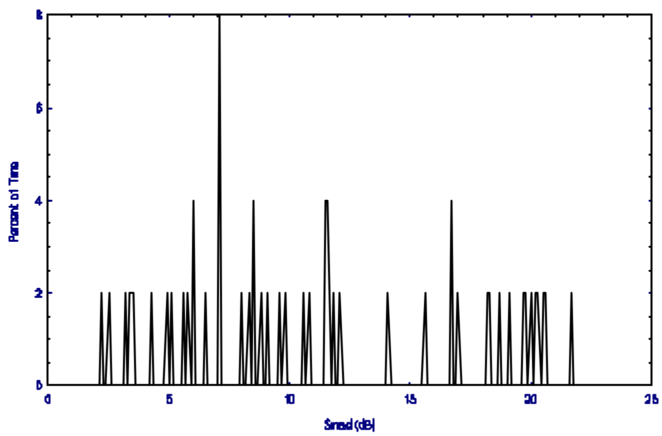

Figure C-6
Channel 286 Base Receive

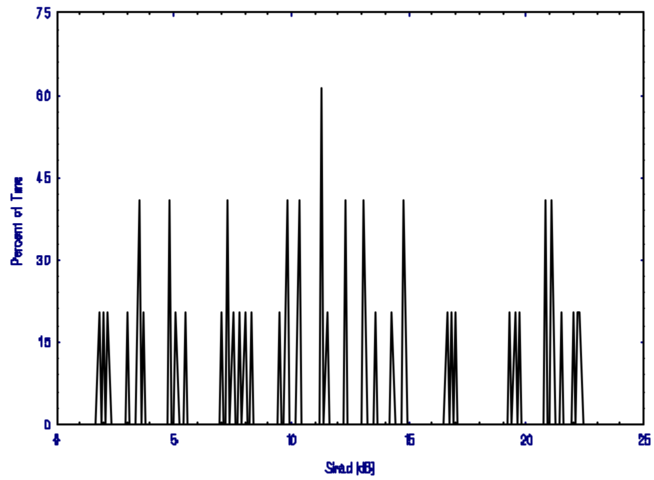

Figure C-7
Channel 227 Base Receive

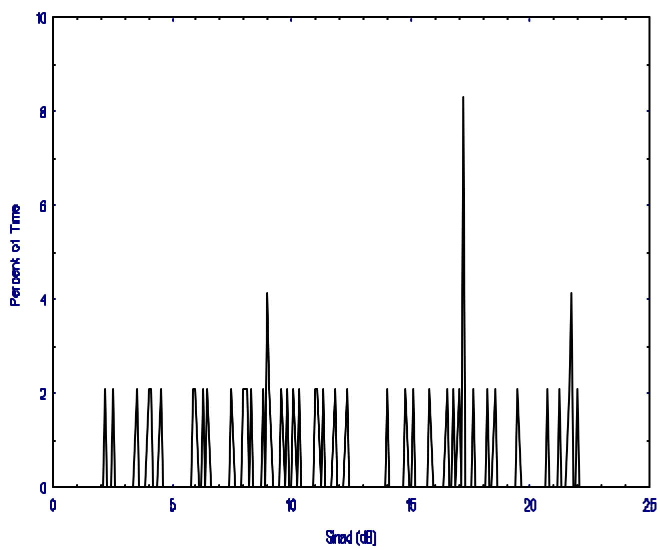

Figure C-8
Channel 287 Base Receive

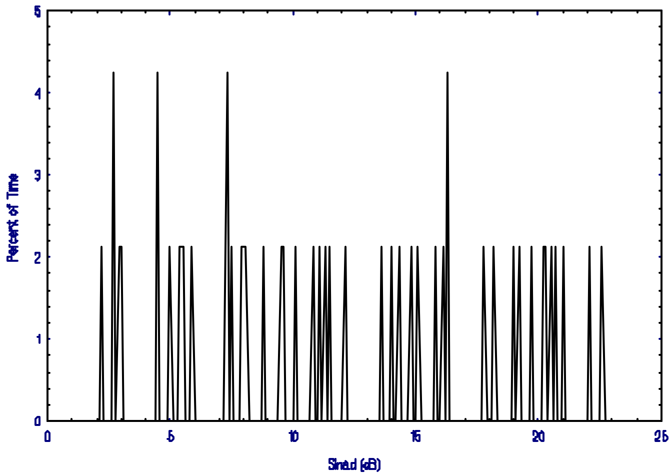

Figure C-9
Channel 228 Base Receive

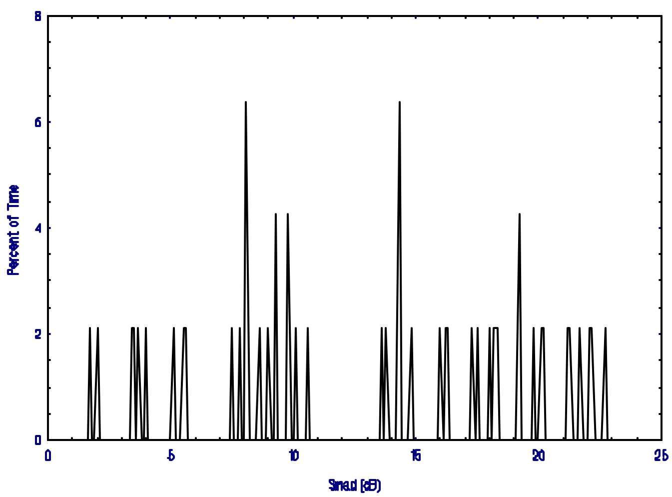

Figure C-10
Channel 283 Base Receive