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AWARE NovaRoam Radio Field Test Results

On Tri-Rail Train

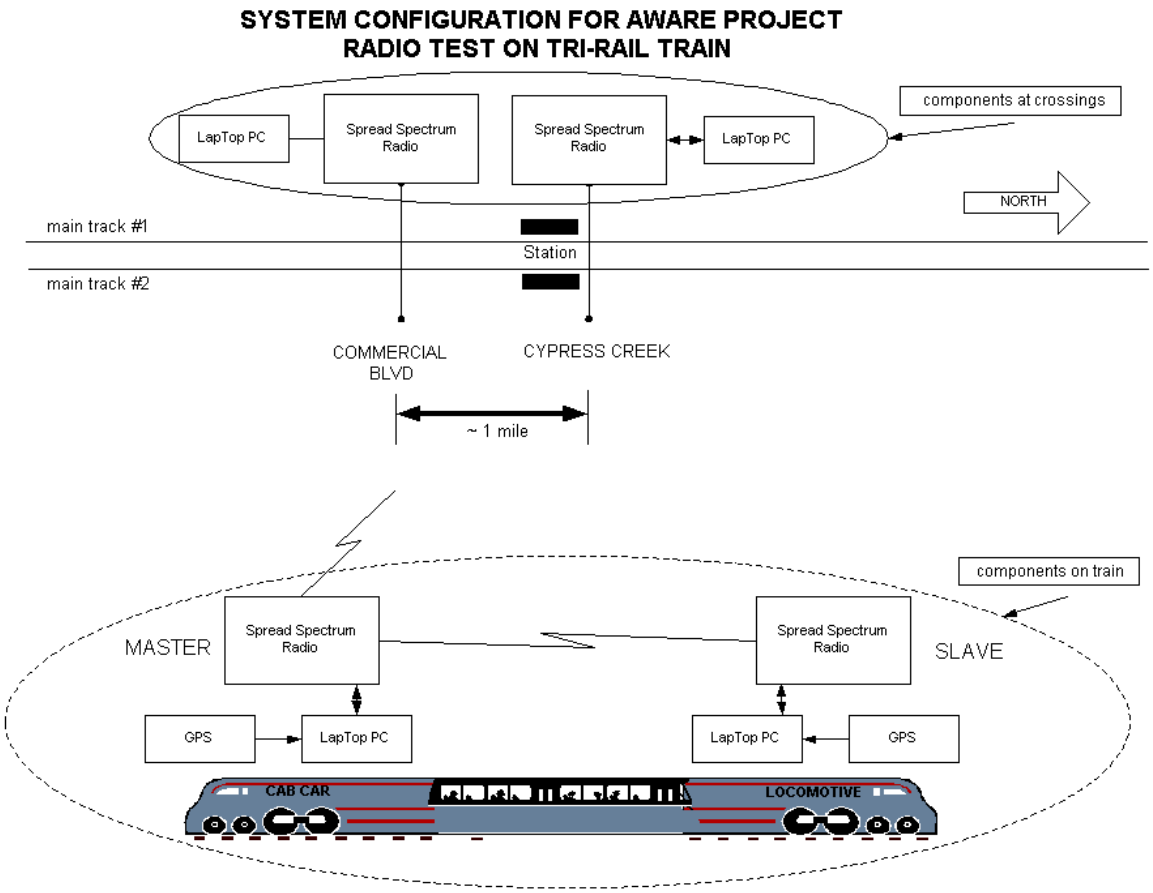
October 12, 2001

To

GEOFOCUS INC.

From

SEAROBOTICS CORPORATION



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1 Introduction

1.1 Purpose

The purpose of this document is to verify that the NovaRoam 900 radios meet the requirements for the AWARE Train project under actual application conditions. These radios were used to connect a simulated MMIT (Master Mobile Information Terminal) with a simulated SMIT (Slave Mobile Information Terminal) as well as two simulated ACCs (Aware Communications Computers) at railroad crossings.

2 System Capabilities and Limitations

The AWARE application requires simultaneous wireless communications between multiple points and the ability to establish communications within a two mile line-of-sight range. The ability of the system to integrate new radios into the wireless network with little effort is also desired.

The NovaRoam 900 radios are designed to support Mobile Ad-Hoc Networking (MANET), where multiple mobile nodes roam a wireless network. The feature set of the NovaRoam radios matches the needs of the AWARE system in the following areas:

- Point-to-Multipoint Communications
- Lack of Master/Slave Designation
- Automatic Routing
- Hopping/Connectivity
- Data Throughput
- Security

3 Performance Tests

The AWARE NovaRoam Radio Field Tests call for the use of four NovaRoam radios connected to four laptops. The laptops simulated the MMIT, SMIT and two ACCs. The MMIT and SMIT were connected to one GPS unit each and logged location data throughout the test. All communications between the MMIT and other units were electronically logged and range results were computed after the test concluded with the GPS data.

These tests were conducted on October 5th, 6th, 7th and 8th in 2001. The Radio Setup was largely performed on the 5th, the Lab Tests were conducted on the 6th, the Dry Run Test was conducted on the 7th, and the Tri-Rail Train Test was conducted on the 8th of October.

3.1 Radio Setup

3.1.1 Radio Serial Numbers

MMIT Radio: 13171
SMIT Radio: 13174
ACC 1 Radio: 13175
ACC 2 Radio: 13172

3.1.2 Antennas

The MMIT and SMIT radios used 12 inch high +4dBi magnetic mount collinear whip antennas, while the ACCs used 4 foot high +8dBi high gain omni antennas. The MMIT and SMIT antennas were mounted on top of the locomotive and cab car, respectively. The ACC antennas are permanently mounted at the railroad crossings on 30’ masts.

3.1.3 Test Software

The laptops were running Windows 2000. The low-level test software used to establish communication was an application called “alive” written by Steve Wettberg. This is a simple ping application that returns an error level based on the success or failure of the ping. A batch file provided by SeaRobotics logged the time and success or failure of every ping attempt. Ping attempts were made to the SMIT, ACC1 and ACC2 by the MMIT at a rate of approximately 1 Hz throughout the test.

3.1.4 Internal Radio Settings

All radios were configured with the following settings:

Interface
- Data Rate: 159 Kbps
- Channel: 31 (915.00 MHz)
- Error Correction: On
- Repeat Mode: Off
- ARQ Control: Off

Broadcast
- Broadcast Repeater: Off
- Broadcast Forwarding: Off

Wireless Routing
- Mode: Basic
- Routing Mode: Dynamic TORA
- Wireless Net Description: No Networks
- Network Responsiveness: 3
- Retry Interval: 3

3.2 Lab Test

A lab test was performed in order to ensure accurate functionality of the radios, laptops and test software prior to performing the dry-run test.

3.2.1 Lab Test Setup

Four laptops were connected via Ethernet to each of the four radios only. The MMIT and SMITs were each connected via a serial link to a GPS receiver.

3.2.2 Lab Test Procedure

Data from the GPS receivers was logged via HyperTerminal. The MMIT system ran a batch file that pings the SMIT, ACC1 and ACC2 continuously while logging the results.

3.3 Dry-Run Connectivity Test

A dry-run connectivity test was performed in order to verify the test setup and operation of all radios using the actual test hardware at the site of the train test without having the radios installed on the train.

3.3.1 Dry-Run Test Setup

The MMIT and SMIT radios and laptop setups were installed in an automobile. The ACC setups were installed at the Commercial Blvd. and Cypress Creek railroad crossings and were connected to the pre-installed road crossing antenna on a 30 foot tower.

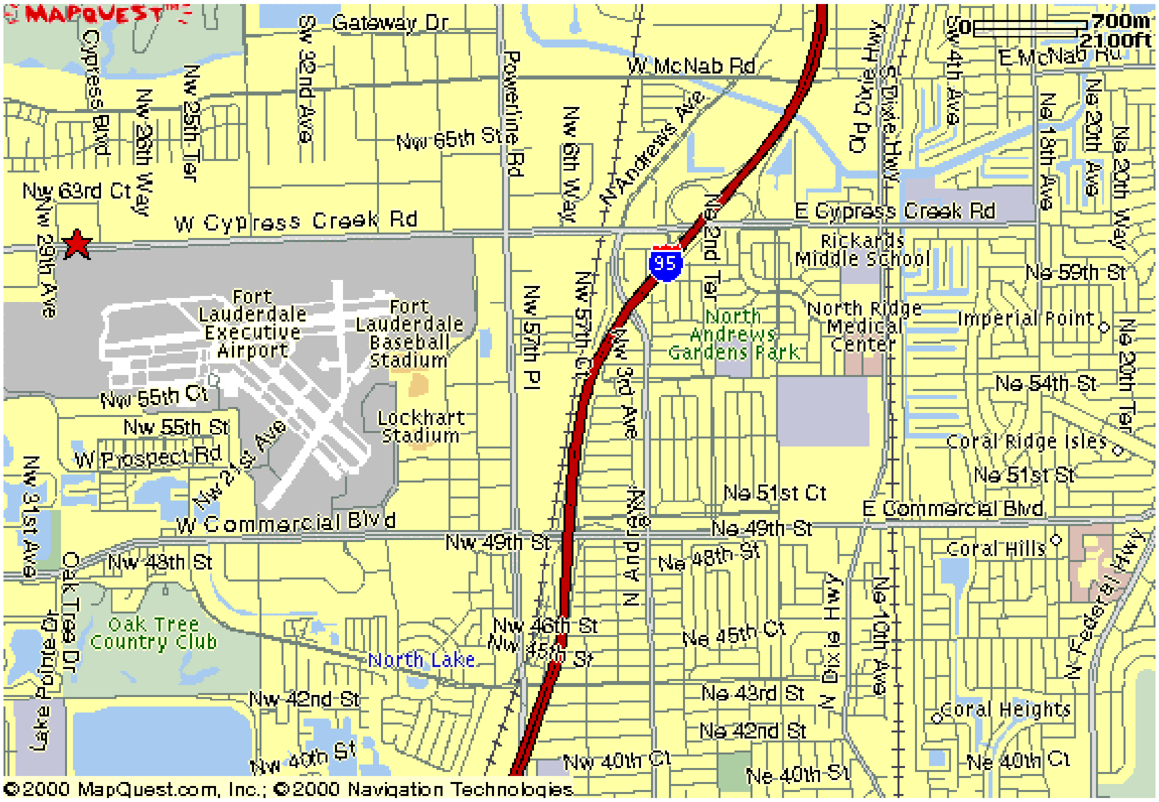

Figure 1: Railroad Crossing Sites

3.3.2 Dry Run Test Procedure

The MMIT system repetitively pinged the ACCs and SMIT systems. GPS and connectivity data were logged. IP routes were monitored to determine whether hopping was occurring.

3.4 Dry-Run Range Test

A range test was performed in order to determine the range of the radios under more realistic operating conditions.

3.4.1 Dry Run Range Test Setup

The MMIT and SMIT radios and laptop setups were installed in an automobile. The ACC setups were installed at the Commercial Blvd. and Cypress Creek railroad crossings and were connected to the pre-installed railroad crossing antennae.

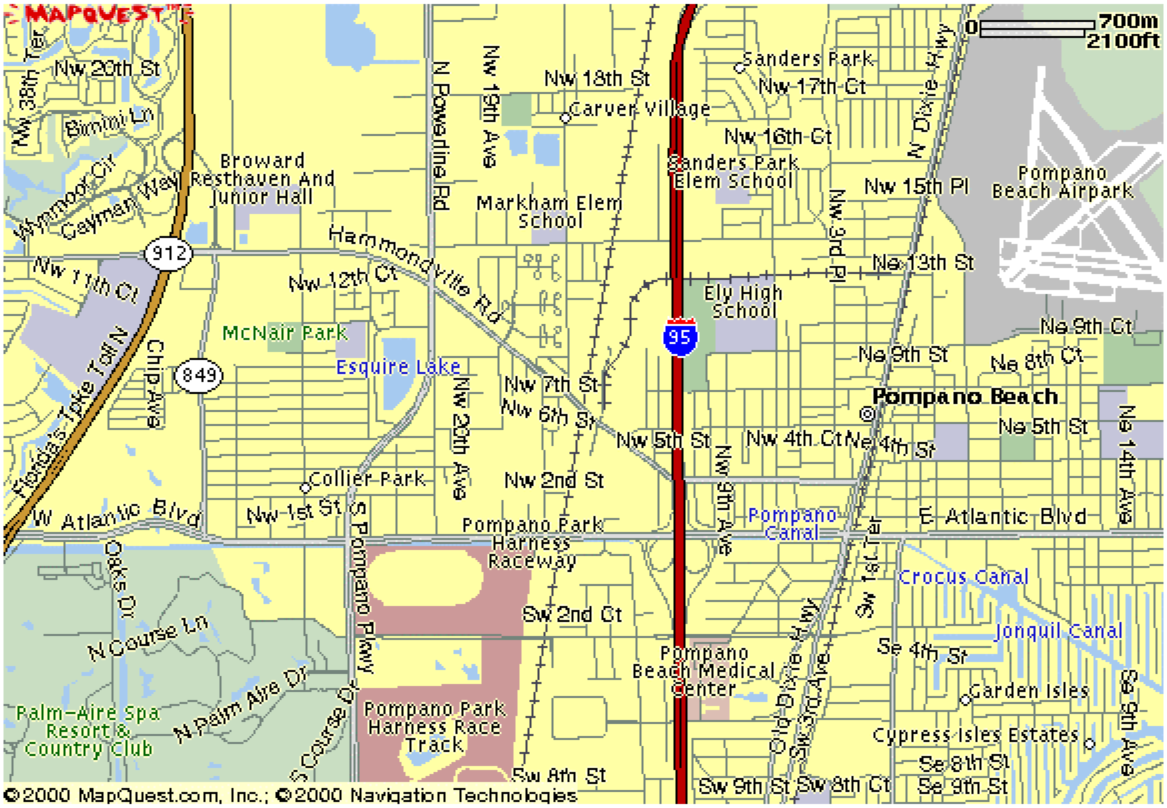

Figure 2: Northern Range (North of Cypress Creek crossing) Testing Area

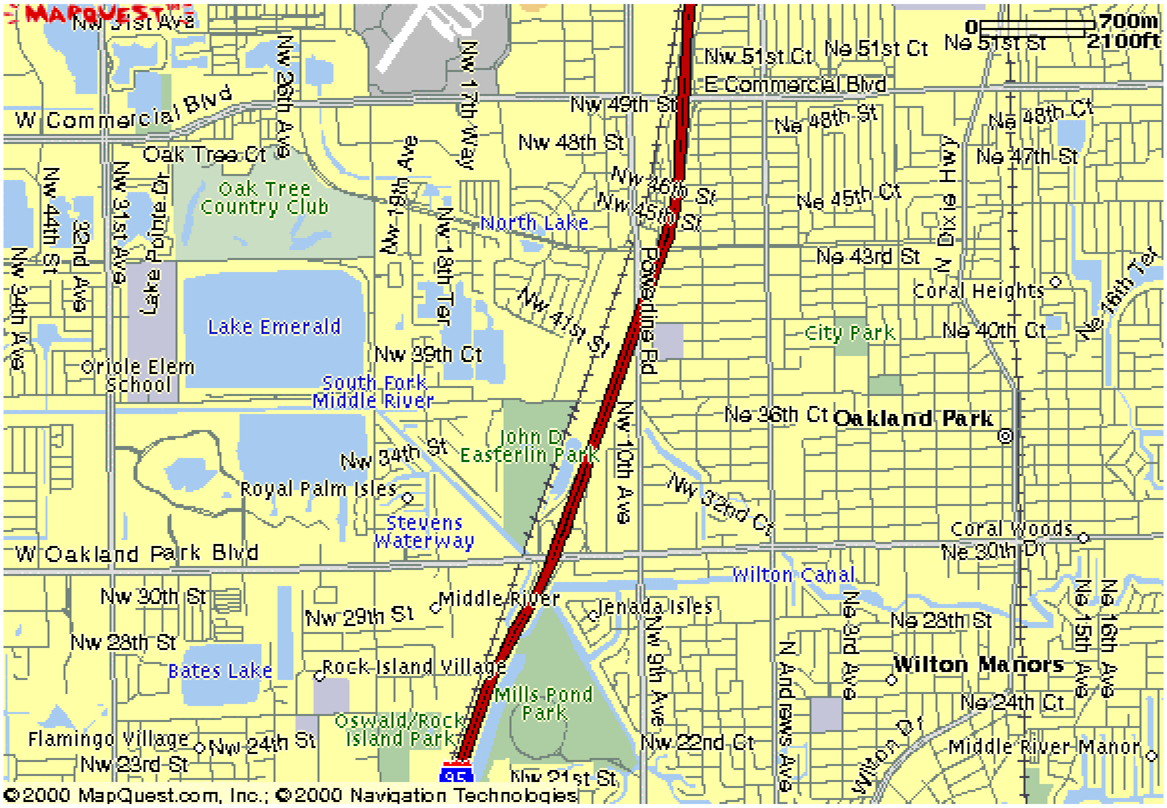

Figure 3: Southern Range (South of Commercial Blvd. Crossing) Testing Area

3.4.2 Dry Run Range Test Procedure

The MMIT system repetitively pinged the ACCs and SMIT systems. The vehicle containing the MMIT and SMIT moved to various locations north and south of the railroad crossings at railroad intersections (in an attempt to provide line-of-sight as much as possible). GPS and connectivity were logged while IP routes were occasionally checked.

3.5 Tri-Rail Train Field Test

3.5.1 Tri-Rail Train Setup

The MMIT radio, laptop and a GPS receiver were installed in the locomotive of the Train. The SMIT radio, laptop and a GPS receiver were installed in the cab car of the train. The ACC setups were installed at the Commercial Blvd. and Cypress Creek railroad crossings connected to the pre-installed railroad crossing antenna.

Figure 4: Tri-Rail System Map

3.5.2 Tri-Rail Train Test Procedure

The MMIT system repetitively pinged the ACCs and SMIT systems logging GPS and IP connectivity data. The train containing the MMIT and SMIT traversed the South Florida Tri-Rail tracks and data was logged from Mangonia Park to Miami Airport in a southerly trip and then from Miami Airport to Deerfield Beach in a northerly trip.

4 Test Results

4.1 Lab Test Results

4.1.1 Radio Connectivity

All radios communicated properly with one another. A test was performed in order to verify that the data was routed from a source radio to a destination radio over a third radio (hopping).

4.1.2 Lab Test Conclusions

All lab tests were successful.

4.2 Dry-Run Test Results

4.2.1 Dry Run MMIT-SMIT Communications

The following Figure 5. depicts the connectivity between the MMIT and the SMIT during the dry-run test. Green indicates successful pings and black indicates that communications were not successful.

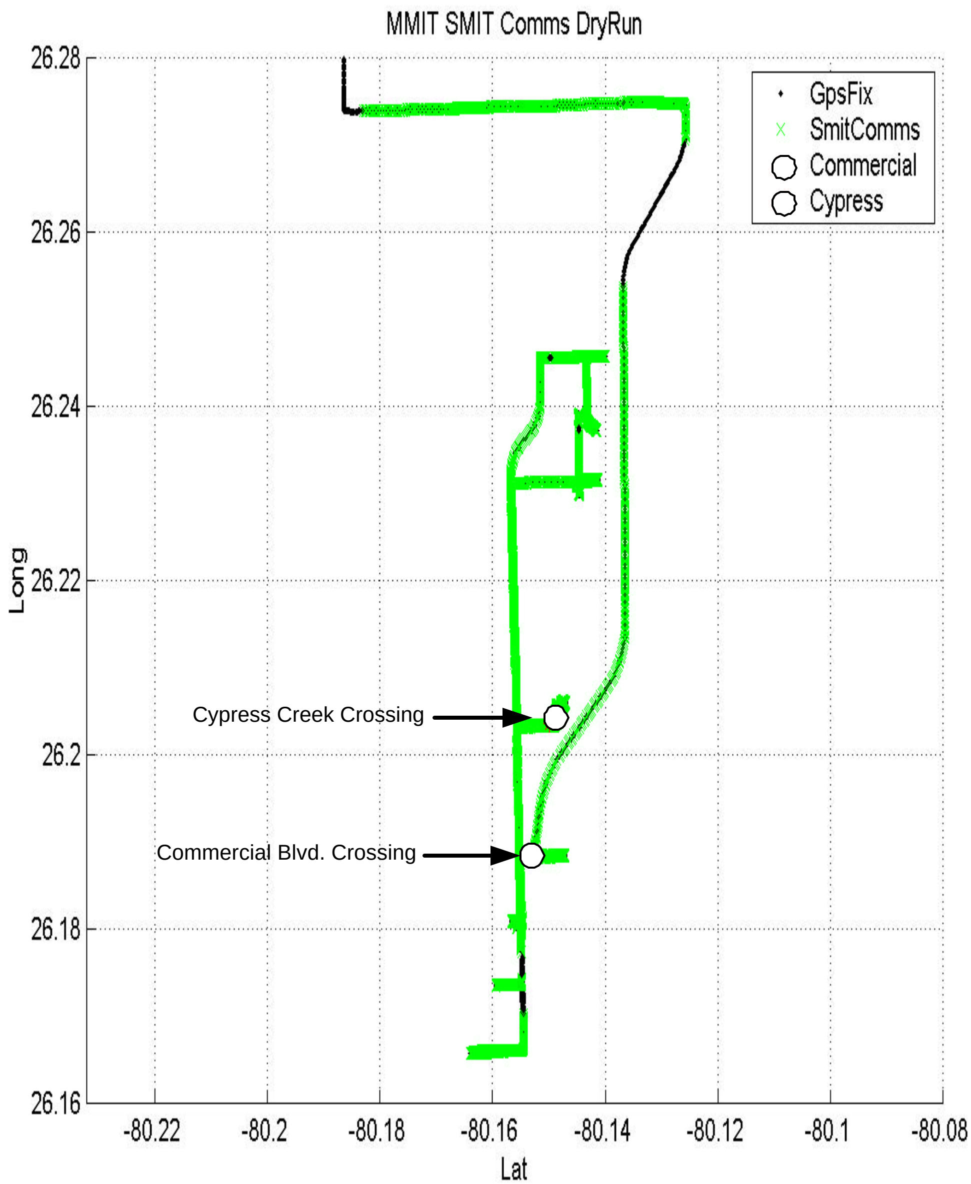

Figure 5: MMIT SMIT Comms Dry-Run

The graph displays the route the vehicle with the MMIT and SMIT took during the dry-run test. See Section 4.2.3
Dry Run MMIT-ACC Communications for details concerning the route that was taken.

4.2.2 Dry-Run MMIT SMIT Communications Conclusions

During the transit in the automobile from SeaRobotics on Lyons Road in Coconut Creek to the first crossing at Commercial Blvd., there was a period where communications between the MMIT and SMIT failed (the black line in the upper-right portion of the graph). Also, when traveling south of Commercial Blvd., there were two other brief stretches where communications were interrupted. It was at this location that a test was performed in order to determine the point at which the communications path was interrupted. The test involved having the MMIT laptop ping the SMIT radio, which was successful, indicating that there was a problem between the SMIT radio and the SMIT laptop. After checking the cabling between the two units, successful communications resumed. Although this may have been a coincidence, manipulating the wires between the SMIT radio and the SMIT laptop seemed to fix the problem during later testing.

4.2.3 Dry Run MMIT-ACC Communications

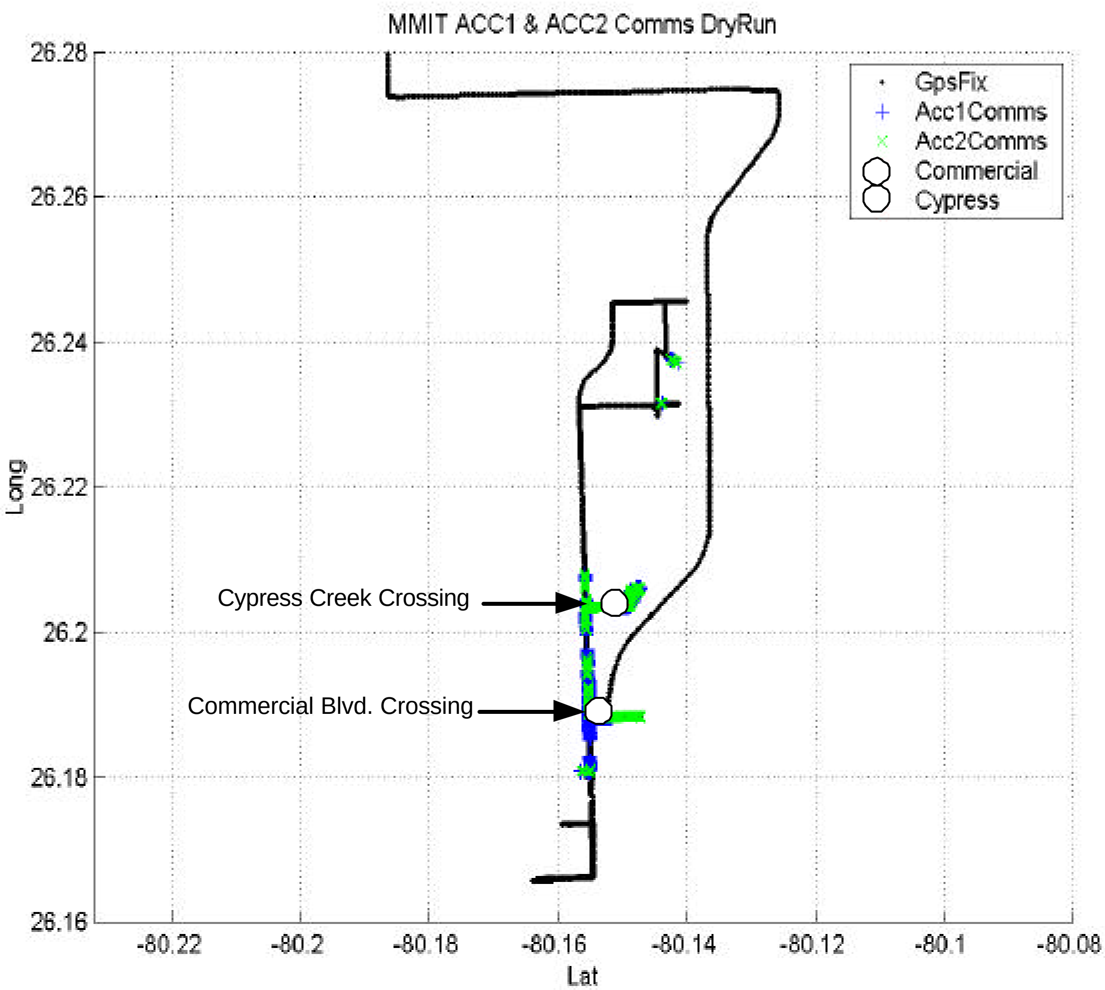

Figure 6: MMIT-ACC Comms Dry-Run

This graph displays the route the vehicle with the MMIT and SMIT took during the dry-run test. The first data points in the upper-left of the graph indicate the route taken from SeaRobotics east down Sample Road to I-95 and then to the first crossing at Commercial Blvd. where the first ACC (ACC1) was installed. The vehicle then traveled north up Powerline Road to the Cypress Creek crossing where the second ACC (ACC2) was installed. Tests were then conducted by traveling north and then east to a point where the road crossed the train tracks. Two other data points were taken further north until communications between the MMIT and the ACCs failed, indicating a relative range of the radios from a vehicle based MMIT. The vehicle then traveled south past Commercial Blvd to railroad crossings on intersecting roads.

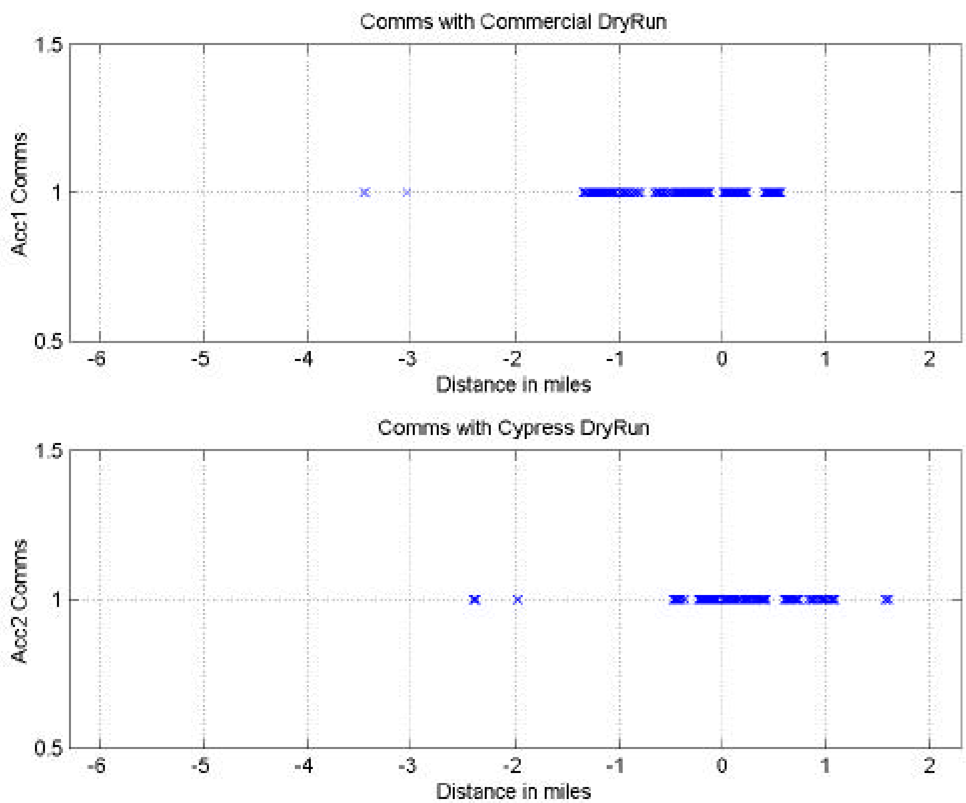

Figure 7: MMIT-ACC Distance Dry-Run

The above graphs indicate the relative range of the MMIT radio from the ACCs where successful communications were possible. The negative distances indicate range from the crossings to the north, the positive distances indicate range to the south of the crossings. ACC1 is Commercial Blvd., ACC2 is Cypress Creek. The blue data points indicate where a ping successfully reached its destination. If there was true line-of-sight between the MMIT and the ACCs throughout the test, then there would be a solid blue line indicating successful communication at all distances until a maximum range was achieved. Because the vehicle traveled on roads (and not along the tracks), the radios' communication paths were blocked by buildings and foliage until the vehicle got to a railroad crossing where line-of-sight was re-established.

4.2.4 Dry-Run MMIT ACC communications Conclusions

The data in **Figure 5: MMIT SMIT Comms Dry-Run** indicated that communication to the north of the Cypress Creek crossing was relatively good, due to a clear line of sight. Communication to the south was relatively poor due to an abrupt turn in the tracks about 0.5 miles south of the Commercial Blvd. crossing.

Specifically, the data in the lower graph of Figure 7: MMIT-ACC Distance Dry-Run indicates a communications range of approximately 2.5 miles to the north from the MMIT to the Cypress Creek (ACC2) crossing. The range of 3.5 miles to the north from the MMIT to the Commercial Blvd (ACC1) crossing indicates that the Cypress Creek radio was forwarding packets received from the MMIT to the Commercial Blvd. Radio at this point. This was then verified by tracing the route of the IP data. A range of approximately 0.5 miles was determined to be the maximum distance that the MMIT could communicate with the Commercial Blvd. crossing when going south because of loss of line of sight at the curve in the tracks.

4.3 Tri-Rail Train Field Test Results

4.3.1 Tri-Rail Train MMIT-SMIT Communications

The following two figures indicate the connectivity between the MMIT and the SMIT on the train throughout the southbound leg. Green indicates successful pings and black indicates that communications were not successful.

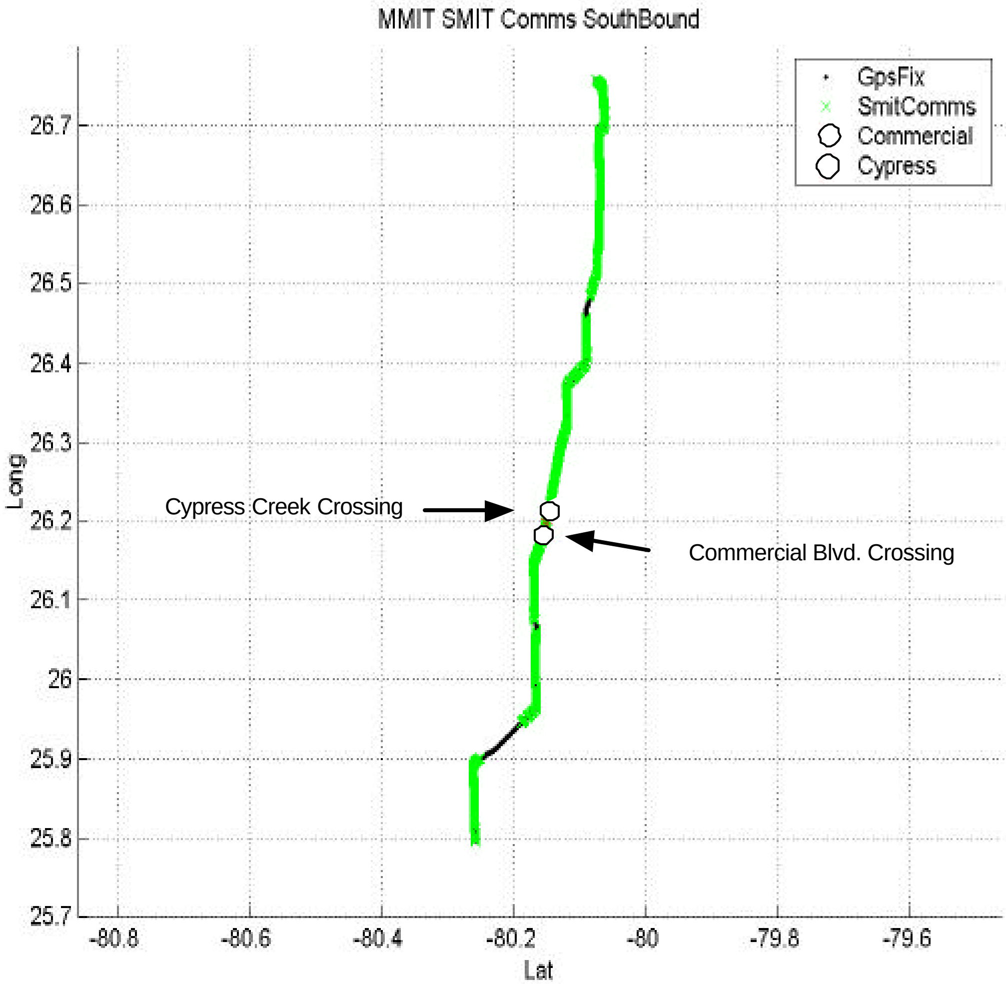

Figure 8: MMIT SMIT Comms Southbound

Figure 8 graphically shows the entire run from Mangonia Park south to Miami Airport. The two clear circles indicate where the two railroad crossing radios were installed. This data reflects the actual coordinates of the railroad tracks, similar to Figure 4: Tri-Rail System Map.

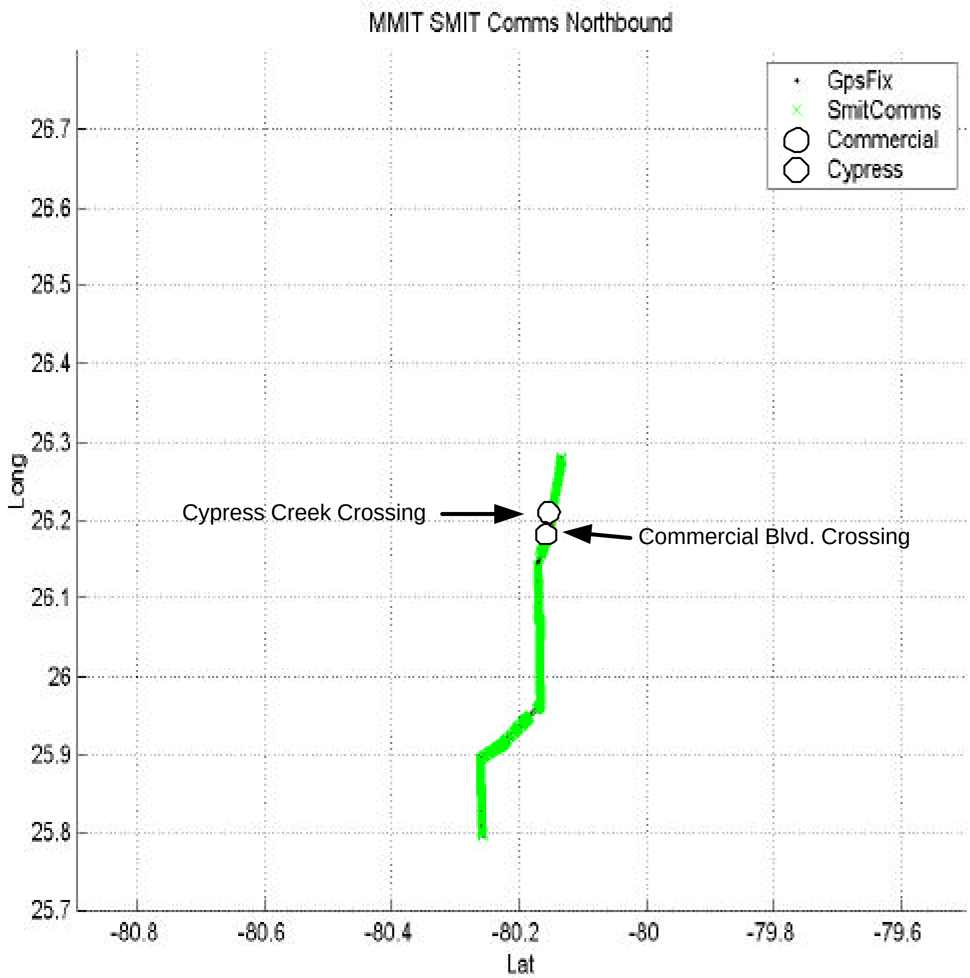

Figure 9: MMIT SMIT Comms Northbound

Figure 9: MMIT SMIT Comms Northbound graphically shows the shortened run from Miami Airport to Deerfield Beach, where data logging was stopped. The two clear circles indicate again where the two railroad crossing radios were installed.

4.3.2 Tri-Rail Train Test MMIT-SMIT Communications Conclusions

From the data one can conclude that communications between the MMIT and the SMIT were in general very good. During the southbound and northbound run there were occasions where the MMIT laptop was unable to ping the SMIT laptop. During those times, a manual ping of the SMIT radio was conducted from the MMIT. All manual ping attempts of the SMIT radio were successful, indicating that radio communications were intact, yet that the communications path between the SMIT radio and the SMIT laptop was broken. It is currently believed that there was a physical connection problem between the SMIT radio (Serial Number 13174) and the Ethernet cable that connected to the laptop computer. Recall that during the dry run tests that manually wiggling the cable connected to the SMIT appeared to correct the problem.

4.3.3 Tri-Rail Train MMIT-ACC Communications

The following two figures indicate the connectivity between the MMIT and the SMIT on the train throughout the southbound leg. Green and Blue marks indicate successful pings with the Cypress and Commercial crossings and black indicates that communications were not successful.

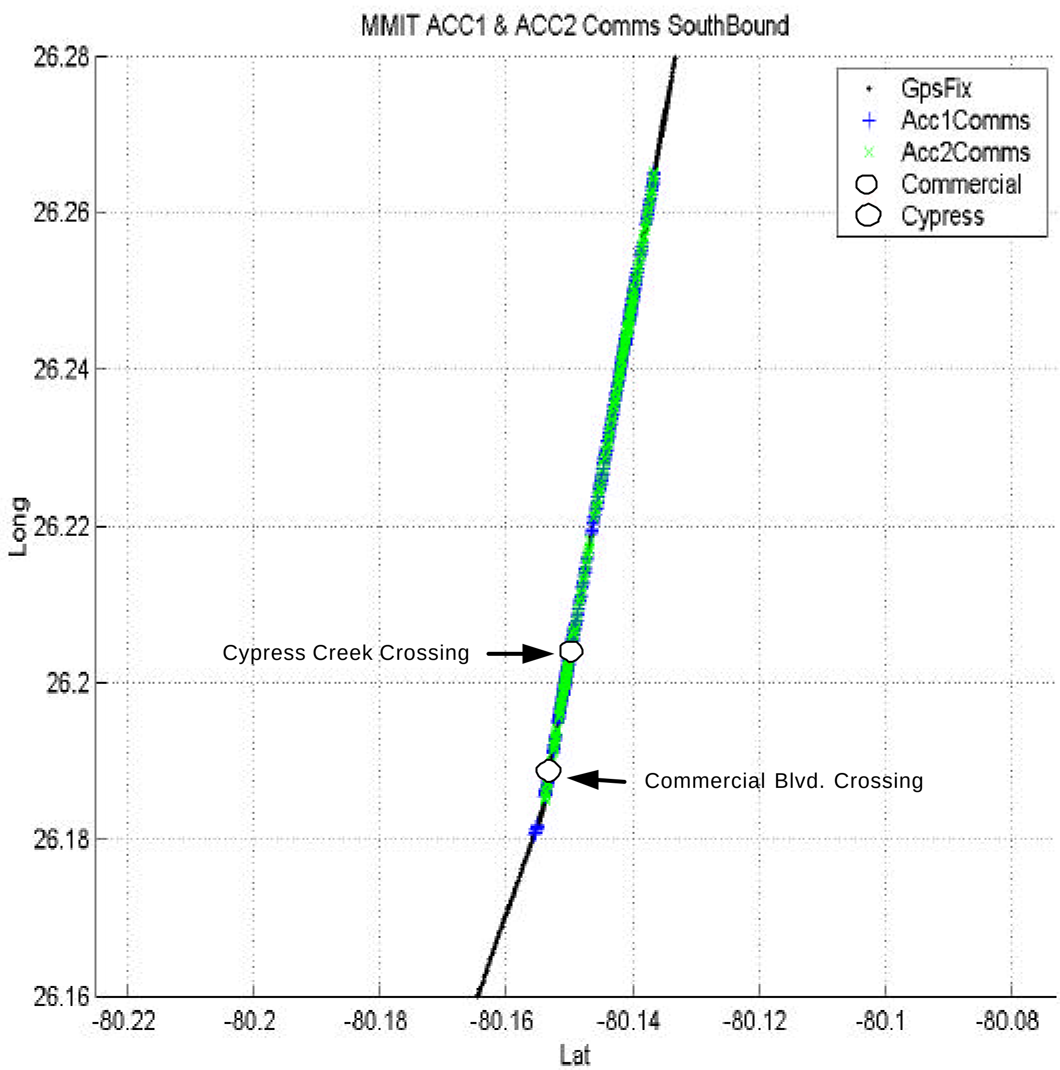

Figure 10: MMIT-ACC Comms Southbound

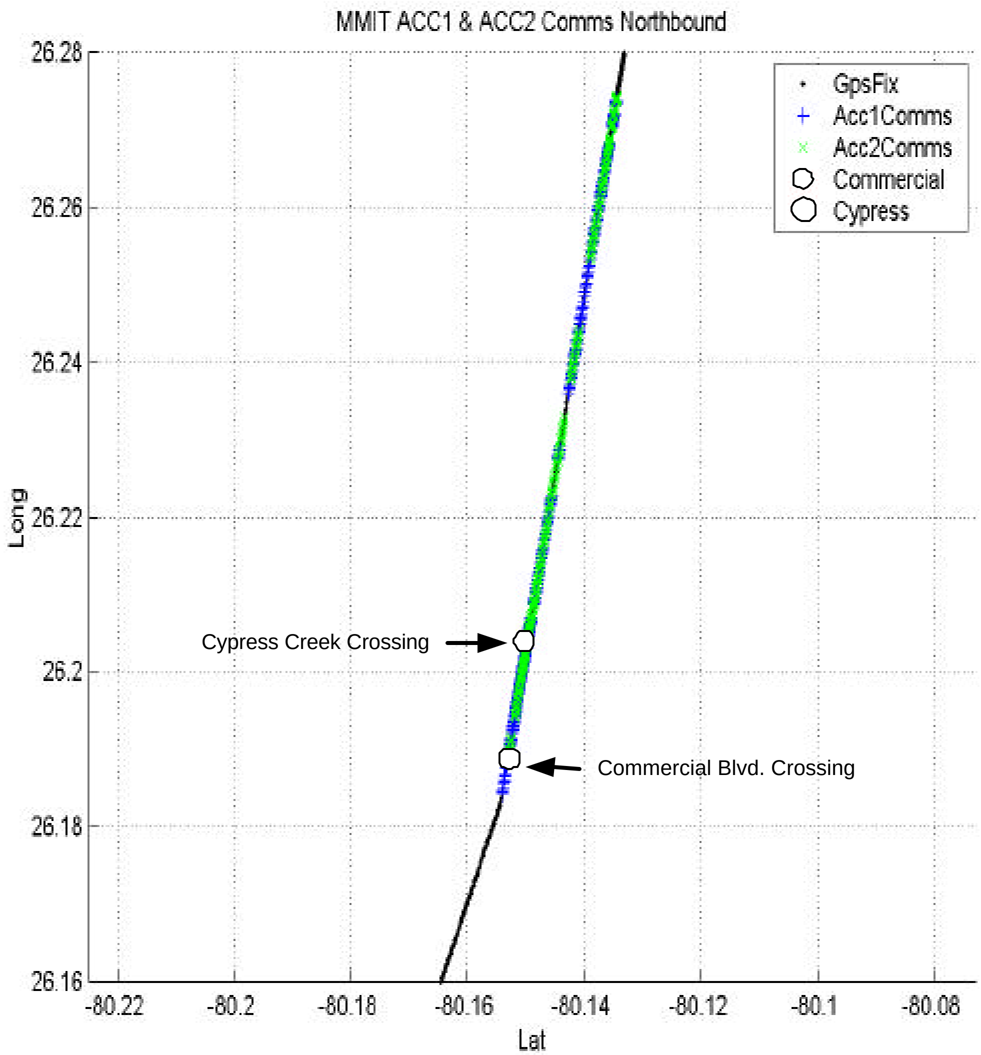

Figure 11: MMIT-ACC Comms Northbound

Figure 10: MMIT-ACC Comms Southbound and Figure 11: MMIT-ACC Comms Northbound graphically show a zoomed-in portion of the track in the area of the Cypress and Commercial crossings (approximately 8 by 8 miles). The two clear circles indicate where the two railroad crossing radios were installed (distance between the two crossings is 1.06 miles).

The following two figures indicate the distance between the MMIT and the individual crossings when communications with that crossing was successful.

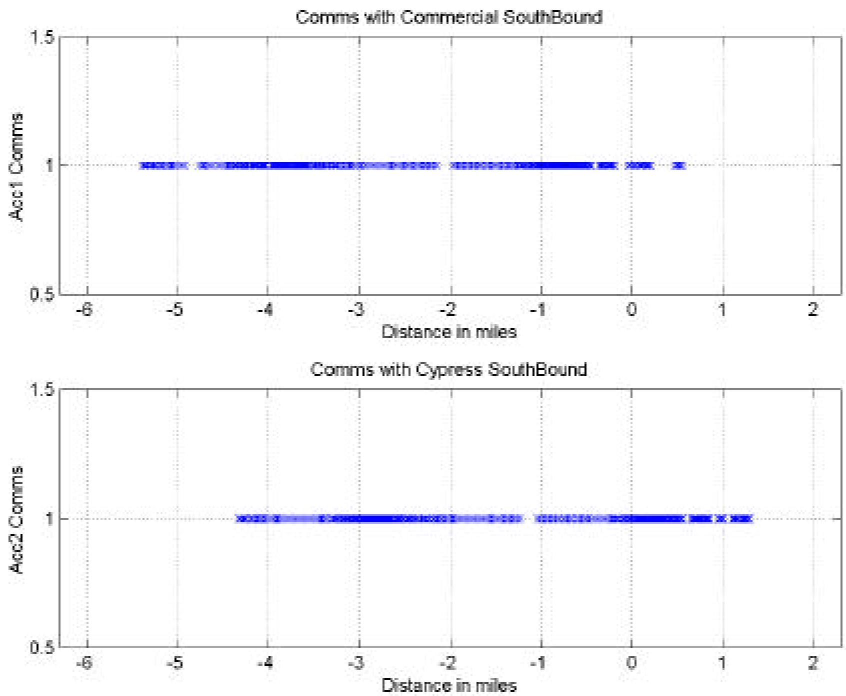

Figure 12: SMIT-ACC Distance Southbound

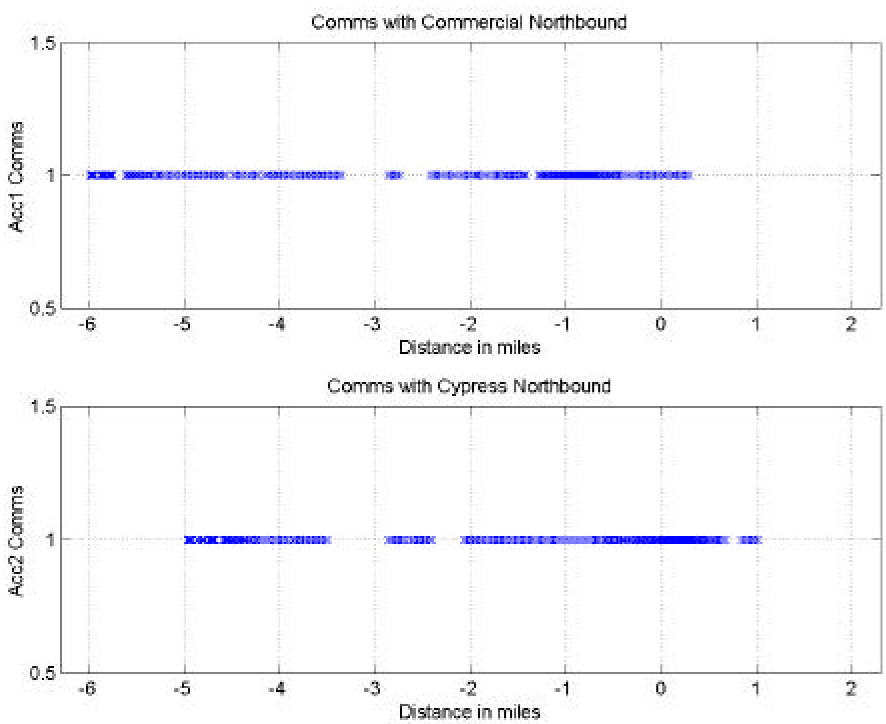

Figure 13: MMIT-ACC Distance Northbound

Figure 12: SMIT-ACC Distance Southbound and Figure 13: MMIT-ACC Distance Northbound graphically show the distance in miles when communications were established between the MMIT and the crossings. The negative distances indicate range from the crossings to the north, the positive distances indicate range to the south of the crossings. ACC1 is Commercial Blvd., ACC2 is Cypress Creek.

4.3.4 Tri-Rail Train MMIT-ACC Communications Conclusions

The data in Figure 10: MMIT-ACC Comms Southbound and Figure 11: MMIT-ACC Comms Northbound indicates that communication to the north of the Cypress Creek crossing was very good, due to a clear line of sight and the increased height of the antenna on the locomotive. Communication to the south of Cypress Creek was relatively poor due to the abrupt turn in the tracks about 0.5 miles south of the Commercial Blvd. crossing. This data matches the data taken during the dry-run in the automobile but with increased range to the north.

Specifically, the data in the lower graph of Figure 7: MMIT-ACC Distance Dry-Run indicates a range of approximately 5 miles to the north from the MMIT to the Cypress Creek (ACC2) crossing. The range of 5 miles to the north from the MMIT to the Commercial Blvd (ACC1) crossing indicated that the Cypress Creek radio was forwarding packets received from the MMIT to the Commercial Blvd. radio. A range of approximately 0.5 miles was determined to be the maximum distance that the MMIT could communicate directly with the Commercial Blvd. crossing when south of that crossing.

It is unclear why there are larger gaps in the range graphs (Figure 12: SMIT-ACC Distance Southbound and Figure 13: MMIT-ACC Distance Northbound). By comparing the Northbound with the Southbound runs, it can be concluded that the gaps do not appear to be related to a particular location. Small gaps could be attributed to interference.

5 Final Conclusions

Overall, the test data indicates that the range of the NovaRoam radios exceeds the range requirement of 2 miles by at least a factor of 2 provided there is a clear line of sight. The ability of the radios to hop to destination radios beyond their direct range indicates that areas where coverage is poor due to obstructions can be overcome by adding radios at other crossings where the train has line of sight.

The Cypress Creek crossing to Commercial Boulevard crossing communications were good. This is a distance of about 1 mile.

Communication between the train and the crossings (Cypress Creek and Commercial Blvd.) when north of the Cypress Creek crossing was good out to 4 miles north of Cypress Creek.

Communication between the train and the crossings (Commercial Blvd. And Cypress Creek) when south of the Commercial Blvd. crossing was good only to 0.5 miles south of Commercial Blvd. where the track makes a turn (i.e. line of sight is not achieved). Once radios are installed at the Powerline/Prospect crossings, however, in the final network system this may not be a problem as long as there is communication between the Powerline/Prospect crossing and the Commercial Blvd. Crossing.

6 Recommendations

In order to demonstrate a 2 mile communications link south of the Commercial Blvd. crossing for this project, we recommend installing a radio at a location at the Powerline/Prospect crossing in order to maintain line of sight at all times to at least one NovaRoam radio.

Prior to installing this radio, a test could be conducted using 2 automobiles equipped with radios very much as we did in the dry run, and one radio at the Commercial Blvd crossing. One auto would simulate a radio near the curve and the second would move out to crossings farther to the south to verify that this is a viable solution.

7 References

Nova Engineering's Web Site: Nova Engineering - Communication Solutions
Nova Engineering: NovaRoam 900 Specifications
Nova Engineering: NovaRoam 900 User's Manual
Nova Engineering: NovaRoam 900 Application Note: Range for Outdoor Links