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Neah Bay Antenna Connectivity Tests and Analysis—November 19, 2001

William D. Ivancic
Glenn Research Center, Cleveland, Ohio

David Stewart
Verizon, Cleveland, Ohio

Ken Edgein and Vincent Pansera
L-3 Communications, Camden, New Jersey

Terry Bell
Lockheed Martin Global Telecommunications, Cleveland, Ohio

Dan Shell
Cisco Systems, San Jose, California

Cecil Miller
United States Coast Guard, Cleveland, Ohio

June 2002

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National Aeronautics and
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Glenn Research Center

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Many thanks to Captain Anthony Ceraolo the entire crew of the Neah Bay for making this test a success and to Commander Michael Flannigan for his support of this project.

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Contents

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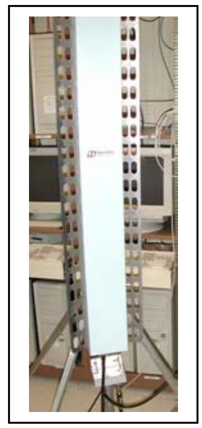
Neah Bay Antenna Connectivity Tests
November 19, 2001

Purpose

The purpose of these tests was to determine the connectivity range and associated data rates for connection between the flat panel antennas on the Federal Building and the dipole and L-3 tracking antennas on the Neah Bay.

Antenna Description



Federal Building Antennas
Flat panel
90-degree beam (3 dB beam width)
19.2 dBi (17 dbd - dB relative to dipole)
Vertical Polarization
Quantity – two (one pointed at 11 degrees true and one pointed at 280 degrees true)
Elevation – 450 ft above Lake Erie

Neah Bay Dipole
Dipole
360-degree beam (omni)
8.2 dBi (6 dBd)
Vertical Polarization
Quantity – One
Elevation – 35 ft above Lake Erie

Neah Bay Tracking
L-3
30-degree beam (horizontal and vertical)
15.0 dBic
Circular Polarization
5 degree tracking accuracy
Quantity – One
Elevation – 20 ft above Lake Erie

Test Configuration Description

Two flat panel antennas are located on the top of the Federal Building. The main beam of the east panel points approximately 11 degrees off true north. The main beam of the west panel points approximately 280 degrees off true north [Figure 1].

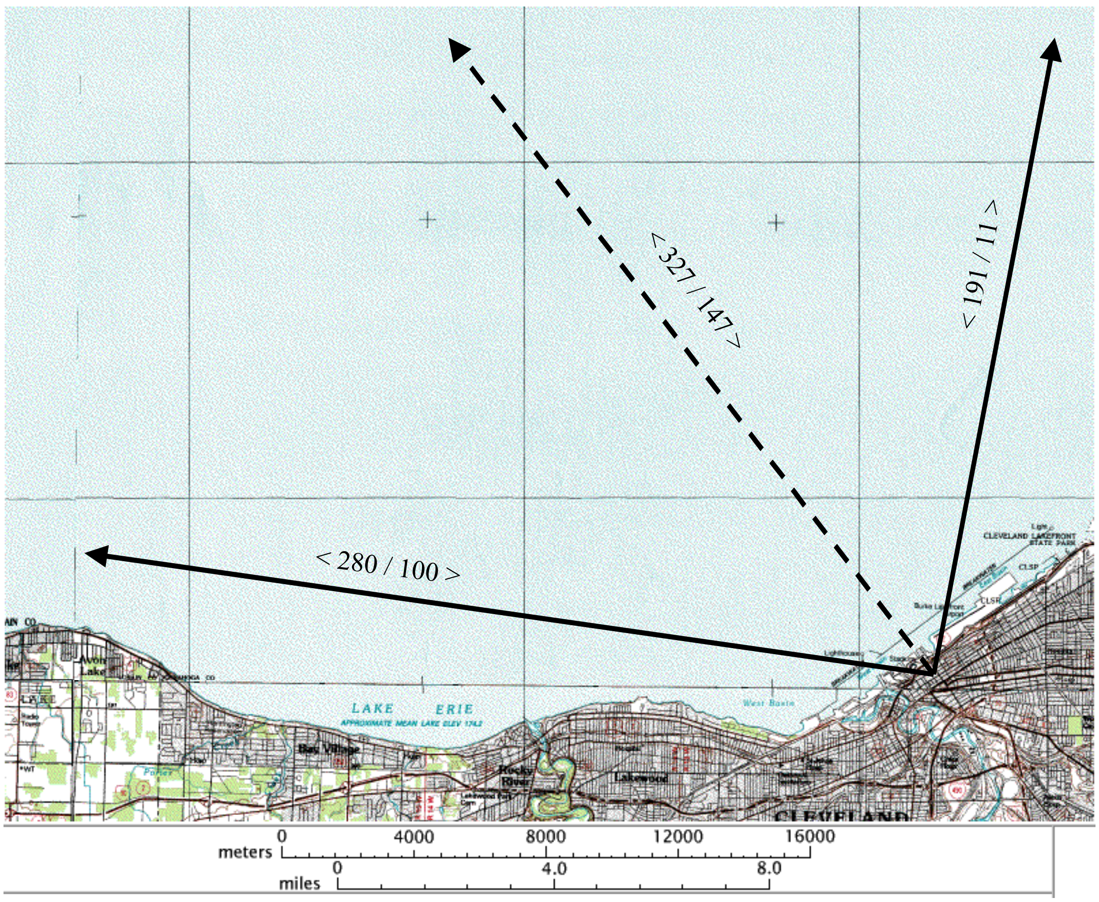


Figure 1 Antennas Main Beams

Federal Building (Lat 41.30.3 Long 81.42.4)

Figure 2 shows the network configuration used for these antenna connectivity tests. One workstation was place on the USCG Federal building LAN while three active workstations were placed on the Neah Bay LAN.

For handoff testing, the wireless bridge of the east beam is configured to communicate with the dipole antenna whereas the wireless bridge of the west beam is configured to communicate with a different antenna such as the L-3 tracking antenna.

For these connectivity distance tests, each antenna onboard the Neah Bay – the L-3 tracking-directional antenna and the omni-directional dipole antenna – utilized either the west or the east beams simultaneously. This is done in order to perform a more accurate comparison of the tracking antenna to the dipole antenna. Only one of these antennas, the L-3 or the dipole, was actively sending user data. This was accomplished by having only one interface on the MR configured for roaming at any one time. The other MR interface was active but not configured to roam. By having both interfaces administratively up, we could telnet into the wireless bridges and monitor the signal strength using two Cisco/Aironet utilities – see appendix. If we allowed both MR antenna interfaces to be active and roaming, we would have had two paths through the same FA, which causes routing problems. Note, both bridges were sending radio link information such as associations and link power status. Thus, we could monitor connectivity on both bridges simultaneously. If a bridge can successfully associate, it is generally capable of transmitting data[1]. If a bridge cannot successfully associate, it definitely is unable to transmit data.

During these tests, the Home Agent and Foreign Agent where not connected to the USCG Intranet because TISCOM approved Type-1 encryptors were not yet in place.

For these tests, the networking equipment was not permanently mounted on the Neah Bay. We simply placed the network equipment on the bridge and ran temporary cabling to the antennas. The dipole antenna was approximately 35 feet above water level whereas the L-3 antenna was approximately 20 feet above water level

[1] It is possible to have the wireless bridge in fringe areas of coverage, where enough of the small association packets can be received to maintain the association, but larger data packets are taking to many errors to be of use. This situation can be recognized when signal strength of approximately 1 is reported back and signal quality is at 0.

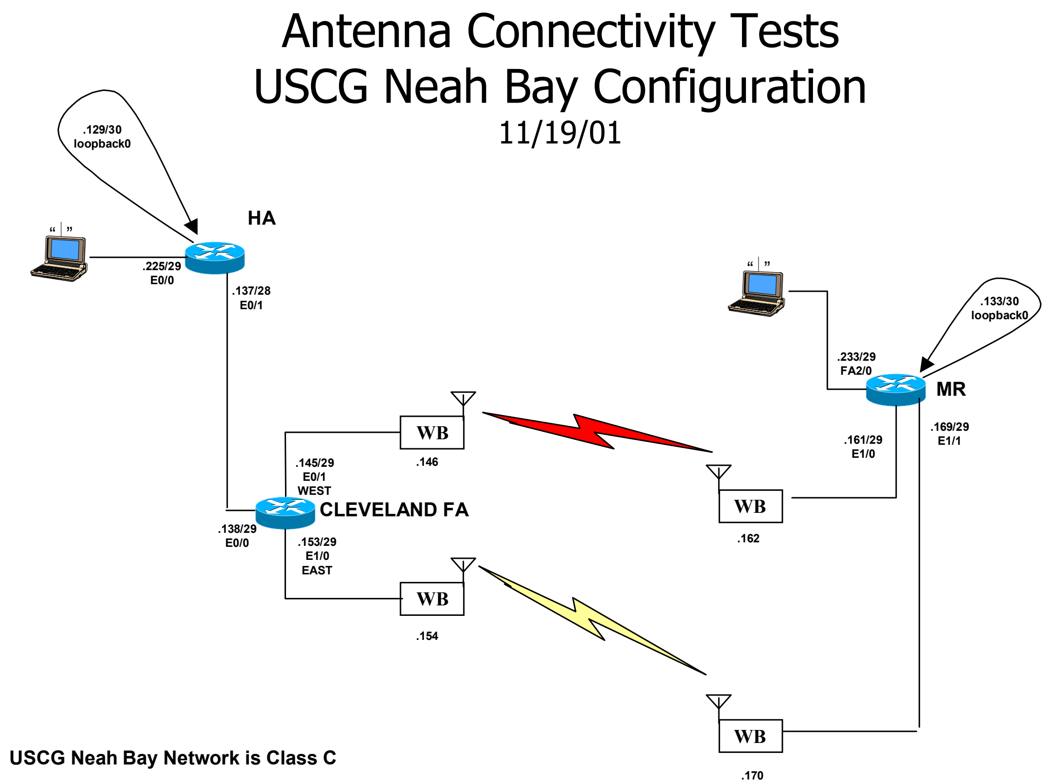


Figure 2 Neah Bay Antenna Connectivity Tests Network Configuration

Pretest

Prior to connectivity testing, the L-3 tracking antenna had to be calibrated to account for distortions of the ambient magnetic field before any testing is performed. This is done by having the vessel execute a full 360 degrees revolution over a period of at least two minutes in relatively flat water. Calibration was performed in seas of 2 feet or less once we were approximately 1 mile outside the Cleveland harbor breakwall.

Calibration of the Digital Gyro Compass was achieved in the first attempt with a compass compensation score of @812. The first digit indicates the quality of compensation achieved with 9 being the highest (8 is very good). The second digit indicates the distortion of the magnetic field --- 1 is highly distorted often caused by installation both near ferrous metals and/ or constant magnetic sources or by installation off "center line". The recommendation is to install the antenna at least 4 feet away from ferrous metals and near the centerline of the ship. In this temporary installation the installation was followed as closely a possible considering the available space. However, installation was not optimal as indicated by the "1" score. However, the high compensation score (as well as observed performance) indicated that the antenna would work OK. The third digit is a counter indicating number of "tries" used to obtain the compensation values.

Continuously though out the testing the azimuth reported by the tracking antenna was compared to the ships navigational equipment reported for the Federal Building. These reading were always within 1 degree of each other indicating that tracking accuracy was within expected limits.

West Beam Connectivity Tests

We ran initial antenna connectivity tests using the West beam. The bridges were set to auto-negotiate from 1 to 11 Mbps. Both bridges on the Neah Bay were configured to associate with the West beam bridge on the Federal building. This was accomplished by setting both Neah Bay bridges to the same SSID as the West beam bridge on the Federal building.

During the West beam tests, the seas were relatively calm 1 to 3 feet averaging 2 feet or less. These test results were taken in the main lobe of the West beam as we steamed out from Cleveland [Figure 1].

Table 1 West Beam Connectivity Tests (Bridges Set For Auto-Negotiation from 1–11 Mbps)

Distance (Nautical Miles)	Antenna	Rate (Mbps)	Signal Quality
< 5.9	L-3-Tracking	11	Good
< 5.9	Dipole	11	Good
5.9 – 6.2[2]	L-3-Tracking	11	Fair
5.9 – 6.2[2]	Dipole	11	Fair
6.3 – 7.5	L-3-Tracking	11	Good
6.3 – 7.5	Dipole	11	Good
7.5	L-3-Tracking	11	Good
7.5	Dipole	11	Good
8.0	L-3-Tracking	11	Fair
8.0	Dipole	2 to 5	Fair
> 8.1	L-3-Tracking	Lost Association	Out of Range
> 8.1	Dipole	Lost Association	Out of Range

Transition from West Beam to East Beam

During our transition from West to East beams, we kept the MR bridges setup to associate with the West beam. We steamed back down the main lobe of the West beam until both bridges associated again at 11 Mbps. This occurred at approximately 8 NM. At the 7 NM point we headed to a position approximately 4.0 NM out in the main lobe of the East beam. During this transition, the L-3 antenna performed slightly better than the dipole. At 4.0 NM, both the L-3 and dipole antennas with corresponding bridges could still associate with the West beam at 11 Mbps [Figure 3].

[2] Approximately 5.9 – 6.2 NM both antennas experienced a noticeable null in signal strength.

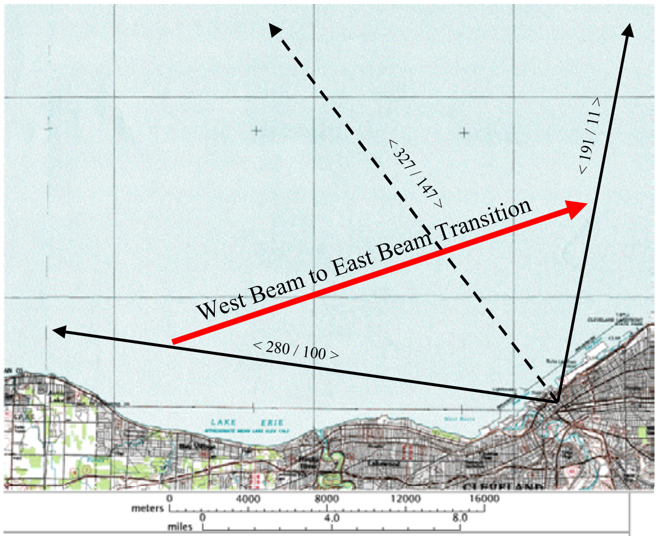


Figure 3 West Beam to East Beam Transition

East Beam Connectivity Tests

We ran initial East beam antenna connectivity tests using the following configuration: The bridges were set to auto-negotiate from 1 to 11 Mbps. Both bridges on the Neah Bay were configured to associate with the East beam bridge on the Federal building.

During the East beam tests, the seas were moderately rough 3 to 5 feet averaging 4 feet or less and we experienced periods of heavy rain. These test results were taken as we steamed out from Cleveland in the main lobe of the East beam [Figure 1].

Table 2 East Beam Connectivity Tests (Bridges Set For Auto-Negotiation from 1–11 Mbps)

Distance (Nautical Miles)	Antenna	Rate (Mbps)	Signal Quality
< 6.3	L-3-Tracking	11	Good
< 6.3	Dipole	11	Good
6.2 – 6.4[3]	L-3-Tracking	2	Fair
6.2 – 6.4[3]	Dipole	11	Fair
6.4-8.4	L-3-Tracking	11	Good
6.4-8.4	Dipole	11	Good
8.5	L-3-Tracking	11	Fair
8.5	Dipole	2 - 5	Fair

[3] A null in power was seen as in the West beam though the East beam null appeared to be larger in magnitude, but shorter in duration.

At this point we steamed back down the main lobe of the East beam until we had stable links at 11 Mbps. We then forced the bridges on both the Federal building and the Neah Bay to 1 Mbps rather than allowing the bridges to auto-negotiate.

Table 3 East Beam Connectivity Tests (Bridges Set For 1 Mbps)

Distance (Nautical Miles)	Antenna	Rate (Mbps)	Signal Quality
< 17	L-3-Tracking	1	Good (Stable)
< 16	Dipole	1	Good (Stable)
17 - 18	L-3-Tracking	1 with occasional loss of association	Fair
16 - 17	Dipole	1 with occasional loss of association	Fair
> 18	L-3-Tracking	Lost Association	Out of Range
> 17	Dipole	Lost Association	Out of Range

Results of link budget and propagation analysis are provided in the propagation analysis section at the end of this report showing nulls in coverage as a function of range between antennas.

Application Tests

We ran Microsoft Netmeeting including chat, whiteboard, sharing and video conferencing with no problems.

Voice over IP was demonstrated and actually provided most of our communications as cell phones would not work at 16 NM off shore.

File transfers were done to and from the Neah Bay. We performed the following file transfer form a laptop on the Neah Bay running Linux to a laptop at the Federal , running Windows 2000. A 995,769 Byte file (minirouter.jpg) was transferred at 11 Mbps and 1 Mbps. Note that the 11:1 data rate increase only gave a 2:1 increase in transfer rate. This could be an indication of higher BER thereby increasing the retransmission requests initiated by the CRC. The measured results are in table 4.

Table 4 FTP Test Results

Link Rate (Mbps)	File Size (Bytes)	Transfer Time (Seconds)	Transfer Rate (kBytes/sec)
1	995769	23.04	43.21
11	995769	12.25	81.30

Caveats

It is important to note that the intent of this test was to verify the performance and range of the Wireless Bridges deployed on the Cleveland Federal Building. The main emphasis was place on data connectivity between the bridges and not signal strength or quality. Thus all conclusions of antenna performance are interpreted from the signal strength, signal quality and bit rate as reported from the wireless bridges [Figures 4 and 5 in the appendix]. Although these readings appear to be relative to the performance of the bridges, the authors are unaware of how accurate or even how the bridge determines the values it reports. In addition, no attempt was made to calibrate or compare the performance of one bridge to another.

The wireless bridges were not characterized; therefore, one could have better receive sensitivity than the other.

The bi-lateral amplifiers were not characterized; therefore, one could have better gain or noise figures then the other.

General Observations

Tracking Antenna provided high data transfer rates, but dropped out approximately the same time as the 8-dBi dipole.

Dipole appeared to perform a little better in rough water than did the tracking antenna as reported by the Cisco bridge link strength tests.

When bridges are set to auto-negotiate, bridges appear to lose connectivity during the crossover from 11 Mbps to 1 Mbps. We believe that what might be happening is that once the link becomes marginal, the default registration and negotiation packets may be sent at 11 Mbps. In any case, auto-negotiation did not perform well. Thus, we set the links to be locked down at 1 Mbps and were able to obtain a range of approximately 17 nautical miles.

Both wireless bridges for the tracking and omni antennas associated to the same parent bridge, thus using the same RF system. Therefore, any degradation of system performance on the Federal Building side would have affected both systems on the ship equally.

Monitoring both sides of each connection indicated that the talk-out from the Federal Building consistently outperformed the talk-in. (e.g. The transmit signal from the Federal Building was received stronger at the ship's receivers then either of the 2 signals received from the ship at the Federal Building[4].) Since this is the case, the wireless bridge associations failed due to lack of receive signal at the parent bridge (Federal Building). Therefore to compare the performance of the 2 antenna systems on the Neah Bay we need to examine the systems from the transmit side. Attenuation between the bi-lateral amp and the bridge has to be factored in for transmit antenna performance, where in the case of the receive side the attenuation can be ignored unless it exceeds the preamp gain of the bi-lateral amp.

---

[4] The extra antenna gain from the Federal Buildings antenna gave more received power on the ship, but is should also capture more flux from the ship transmissions. Theoretically it shouldn't make any difference where the antenna gain is except in the case of interference/noise in which case array gain (and nulls) will show a difference. Note that in the VHF and higher bands, background noise is not a consideration. However, man-made interference is. For instance, man-made noise often occurs around 2.4 GHz due to microwave ovens, etcetera. We did not perform any inference measurements prior to these tests.

At approximately 15 nautical miles, an observation that as the ship increased in pitch and roll the signal from the tracking antenna was fading at the parent bridge.

RF Configurations

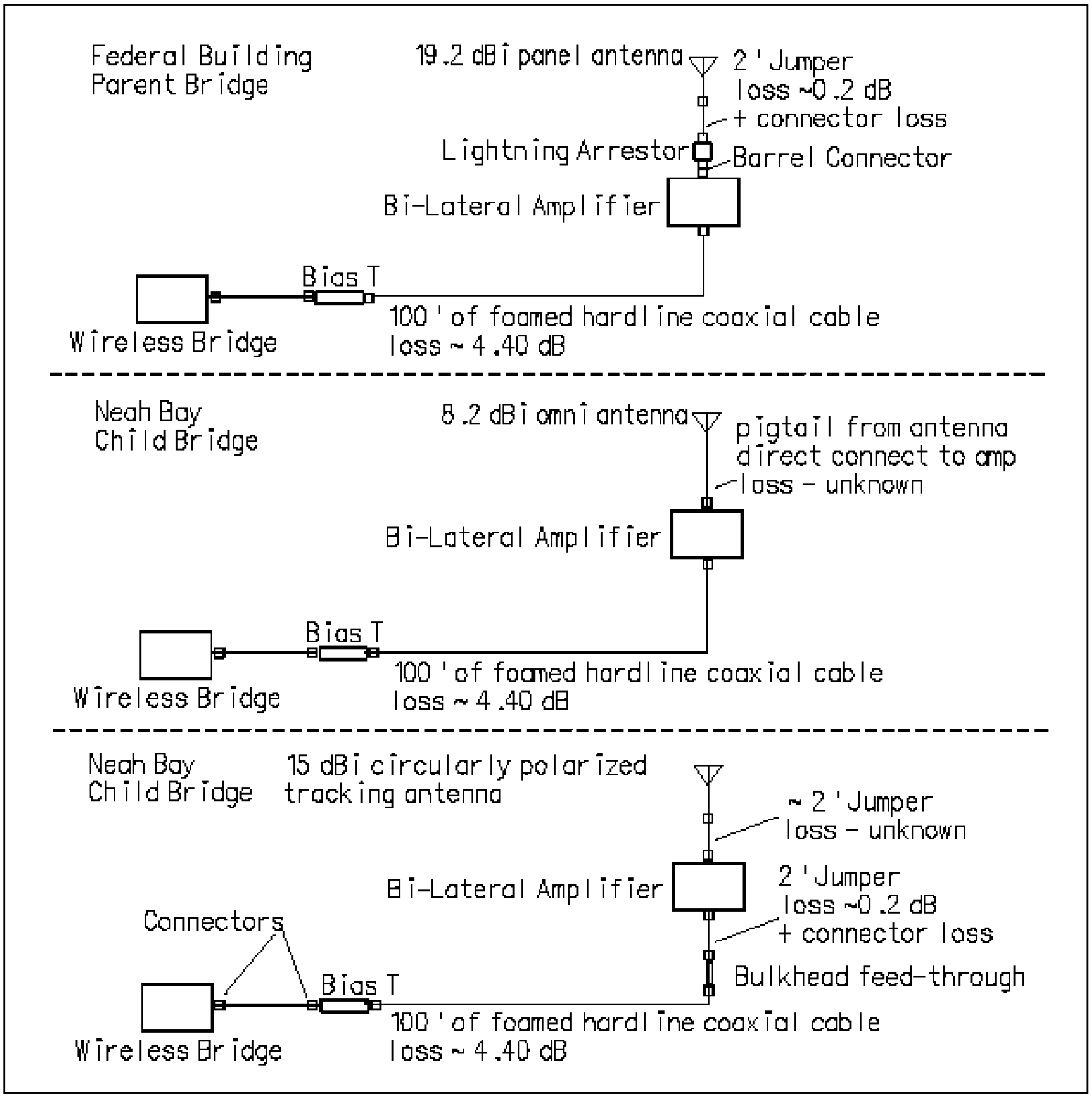


Figure 4 RF Topologies at the Cleveland Federal Building and the Neah Bay

Bi-lateral Amplifier gain
20 dB transmit 17 dB receive

Wireless bridge receive sensitivity
-83 dBm @ 11Mbps -90 dBm @ 1Mbps

Neah Bay's Antenna Systems

Both antenna systems use the same type of bi-lateral amplifier system and transmission line. The only difference between the omni antenna system and the tracking antenna is that the tracking system has a bulkhead feed-through, a 2' jumper and 2 additional connections on the bridge-side of the bi-lateral amplifier, plus a flexible jumper and one additional connection on the antenna side.

<u>Antenna Comparison</u>

Tracking Antenna	15.0 dBi circularly polarized	
Omni Antenna	8.2 dBi vertically polarized	
Difference in Gain	6.8 dB	
Polarization	-3.0 dB	subtract 3 dB for circular polarization[5]
2 Jumper	-0.4 dB	line loss[6]
3 connection	-1.5 dB	connection loss[7]
Feed-through	- 0.3	loss unknown
Difference	1.6 dB	gain tracking antenna over omni

<u>Difference in Gain Equates to Distance</u>

The link equation is given by [1][8]:

$$[1]\ (C/N_o)dB = 10\log(P_T G_T) - 20\log(4\pi d/\lambda) + 10\log(G_R/T_R) + 10\log L - 10\log k$$

$10\log(P_T G_T) \equiv EIRP_{Transmitter}$
$d \equiv$ distance
$G_R/T_R \equiv$ Figure of merit gain-to-equivalent noise temperature at the receiver
$L \equiv$ Losses
$k \equiv$ Boltzmann's constant

Since the receive signal should drop out at the same carrier-to-noise ration for both the dipole and tracking antenna, we can reasonably determine the difference in expected distance by setting the setting the carrier-to-noise ratios the same for both antenna link budgets. This results in the following:

[5] Tracking antenna is circularly polarized and the antenna on the Federal Building is vertically polarized causing a 3 dB reduction in performance.
[6] 2' jumper from bulkhead to amp has line loss of ~0.2 dB for cable alone. The loss of the flexible jumper is unknown and assumed to have the same loss.
[7] Connector-to-connector loss estimated at 0.5 dB per connection (rule of thumb).
[8] K. Feher: "Digital Communications Satellite/Earth Station Engineering," pages 40-44, Prentice-Hall, 1983

$$(EIRP_{tracking} - EIRP_{dipole})_{dB} + (L_{tracking} - L_{dipole})_{dB} = 20\log(d_{tracking} / d_{dipold})$$

$$\Delta Gain \equiv (EIRP_{tracking} - EIRP_{dipole})_{dB} + (L_{tracking} - L_{dipole})_{dB}$$

$$[2]\ d_{tracking} = d_{dipole} \log^{-1} \frac{(\Delta Gain)}{20}$$

Since our gain difference including losses is estimated to be 1.6 dB, the distance we should have achieved with the tracking antenna should be:

$$d_{tracking} = d_{dipole} \log^{-1} \frac{(1.6)}{20} = 1.20x(d_{dipole})$$

or 19.2 nautical miles versus 16 nautical miles in free space. Nulls caused by destructive interference due to reflections off the water will modify this. An analysis of this effect is shown in the propagation analysis section.

If two circularly polarized tracking antennas were utilized and the losses minimized by removing some of the extraneous cabling and connectors within the tracking antenna RF chain, the gain difference would be more in the order of 14dB. This would theoretically result in 5 times the distance obtainable by use of the simple dipoles. However, one is ultimately restricted by line of sight requirements. The additional 14 dB would provide additional margin over the dipoles, which is highly desirable.

Conclusions

Although the difference in antenna gain seems significant, the overall difference in system gain between the 2 antenna systems is approximately 2 dB, which should have resulted in connectivity out to 20 NM. However, we only obtained an increase of approximately 2 NM at 1 Mbps transmission rates. Possible reasons for this include:

- There was more loss in the tracking system RF chain than we estimated (actual power meter measurements where not performed)
- The tracking antenna was mounted lower on the boat than the dipole and may have been experiencing greater reflections off surface structures resulting in interference or line-of-sight blockage.
- 2nd order effects are not taken into consideration with the simple link equation.

The wireless bridge and bi-lateral amplifier used in each system were uncalibrated and uncharacterized; therefore, it is speculative as to say one antenna system out performed the other.

It is unclear why the tracking antenna transmit was experiencing fading during the increased period of pitch and roll of the ship. Possible explanations include:

1) A portion of the ship (stack) may have been blocking or distorting the transmit beam as the ship pitched and rolled.
2) The pitch and roll compensation system may not be designed for Lake Erie's faster wave action. The current antenna-tracking algorithm is "open loop". The antenna is instructed to track a point in space based on Lat/Lon of the transmitter and receiver. It is possible to "tighten" the performance if needed to work on a

smallish vessel in higher sea states by implementing a second control loop based on RF strength into the feedback so performance will improve under those conditions.

3) Location of the propagation nulls is very dependent on the shipboard antenna height. The distance at which a null is found on the 35 ft high antenna is much different from that seen on an antenna mounted at 20 ft. When the Neah Bay was bouncing around in 4-6 foot seas the real antennas heights were continuously changing and percentage-wise more for the lower antenna.
4) The pitch and roll compensation system was malfunctioning

In order to provide a high percentage of link availability a link margin of 6-10 or even more dB has to be built in to keep the BER low or the ARQ/CRC will slow the link down with retransmissions. Thus, one would have throughput, but not at the rates being advertised.

Propagation Analysis

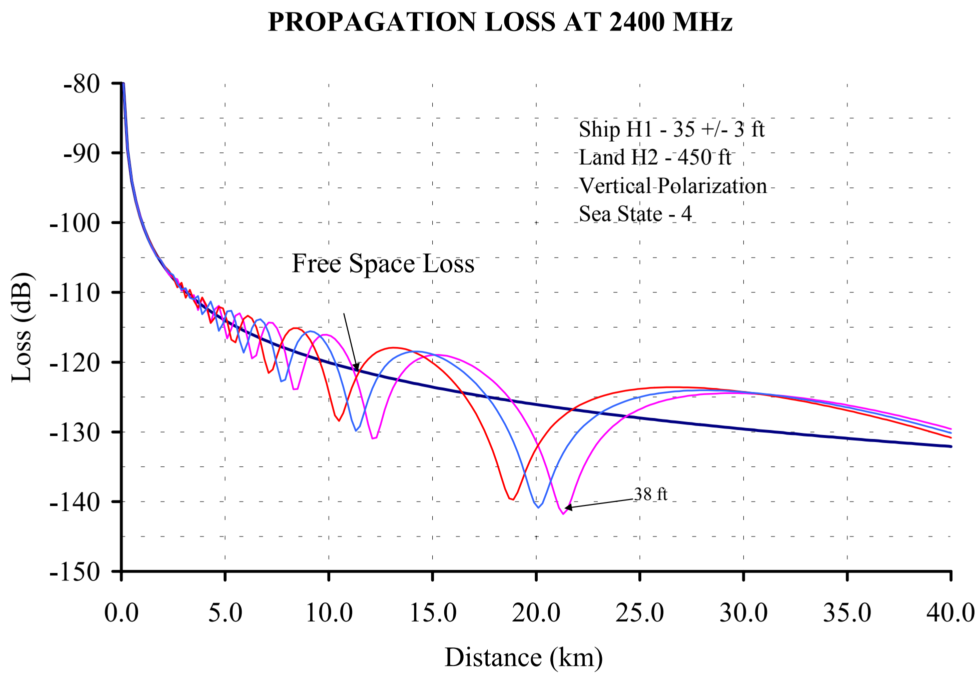
RF Model

The propagation loss of the data link was modeled using the Engineers Refraction Effects Prediction (EREPS) software program. The program requires inputs for the antenna heights, antenna polarization, frequency, and wind speed. Based on the specified input parameters, the program outputs the propagation loss versus distance over seawater and the free space loss. The transmit and receive antenna height input parameters can be interchanged and will yield the same propagation loss curve due to antenna reciprocity.

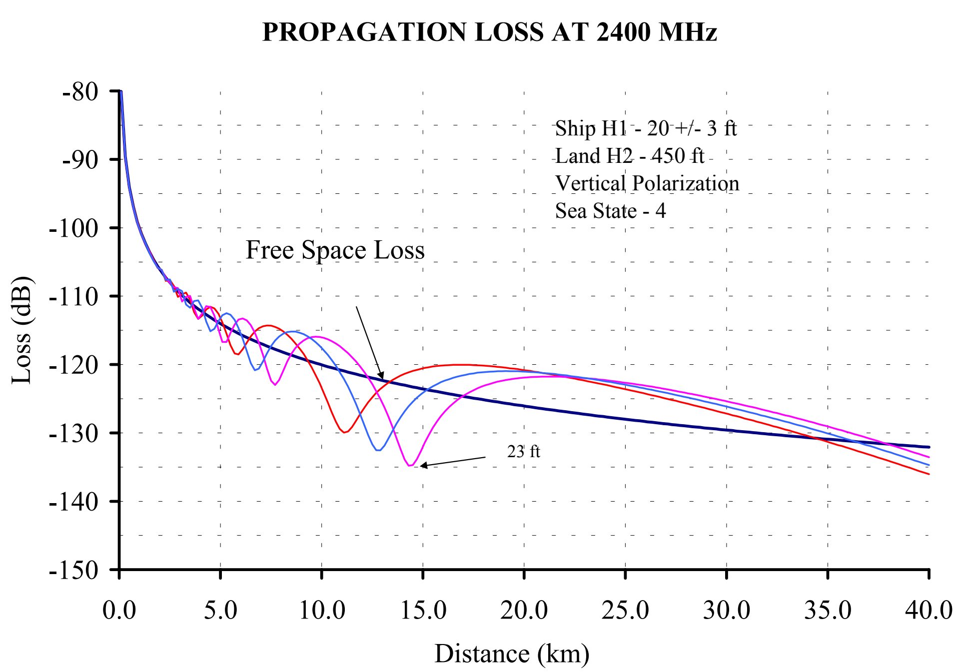
The EREPS model outputs the long-term fade component of the propagation loss, which does not include the short-term fade component that pertains to the signal variability. The link availability can be computed from the short-term variability when the signal statistics (probability distribution function) are known, but, in general, this is not the case. However, if the short-term loss is caused entirely by muiltpath (this is a good assumption at this frequency since atmosphere gases and rain attenuation can be neglected), then the short-term fading component can be described as a Rayleigh probability distribution function. The Rayleigh probability distribution function describes the worst-case fading, in the absence of a dominant LOS component, which can occur in a multipath environment between the transmitter and receiver path. A plot of the Rayleigh probability distribution function versus time availability indicates a link that requires 95% time availability would require a 13-dB margin [Graphs 3 and 4].

The EREPS program predicts the long-term fade component of the propagation loss that includes null locations caused by multipath between the receiver and transmitter. Graphs 1 and 2 depict the sensitivity of the null location that results when the ship's antenna height is perturbed by +/-3 ft due to the spatial movement of the null caused by the seawater motion [Graphs 1 and 2].

Graph 2: Dipole Antenna Null Sensitivity



Graph 1: Tracking Antenna Null Sensitivity

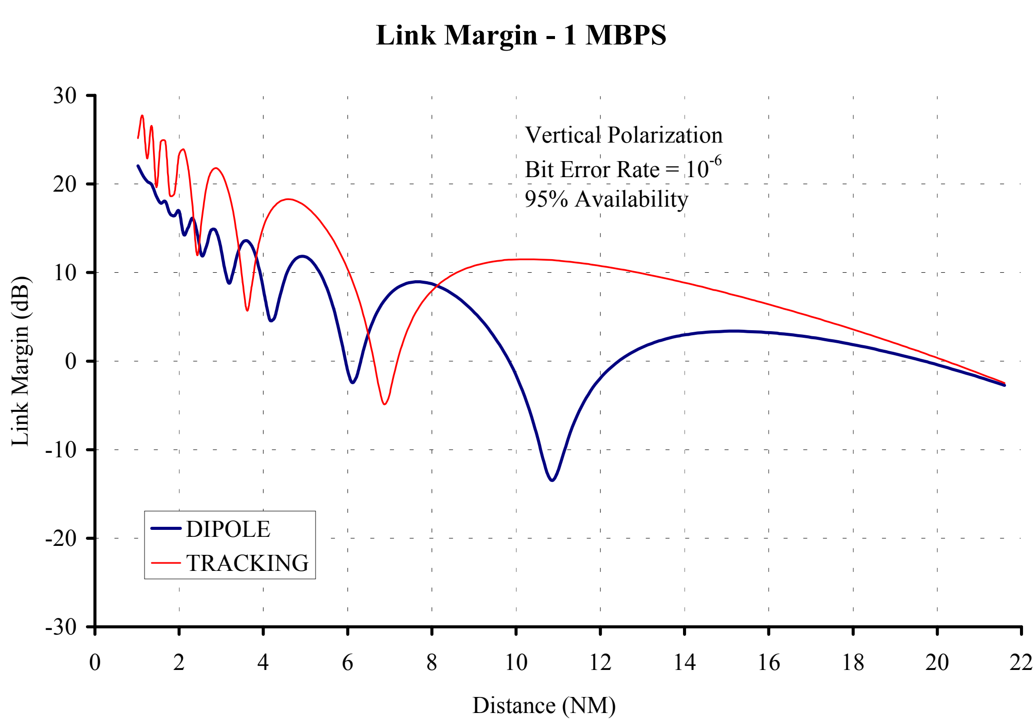


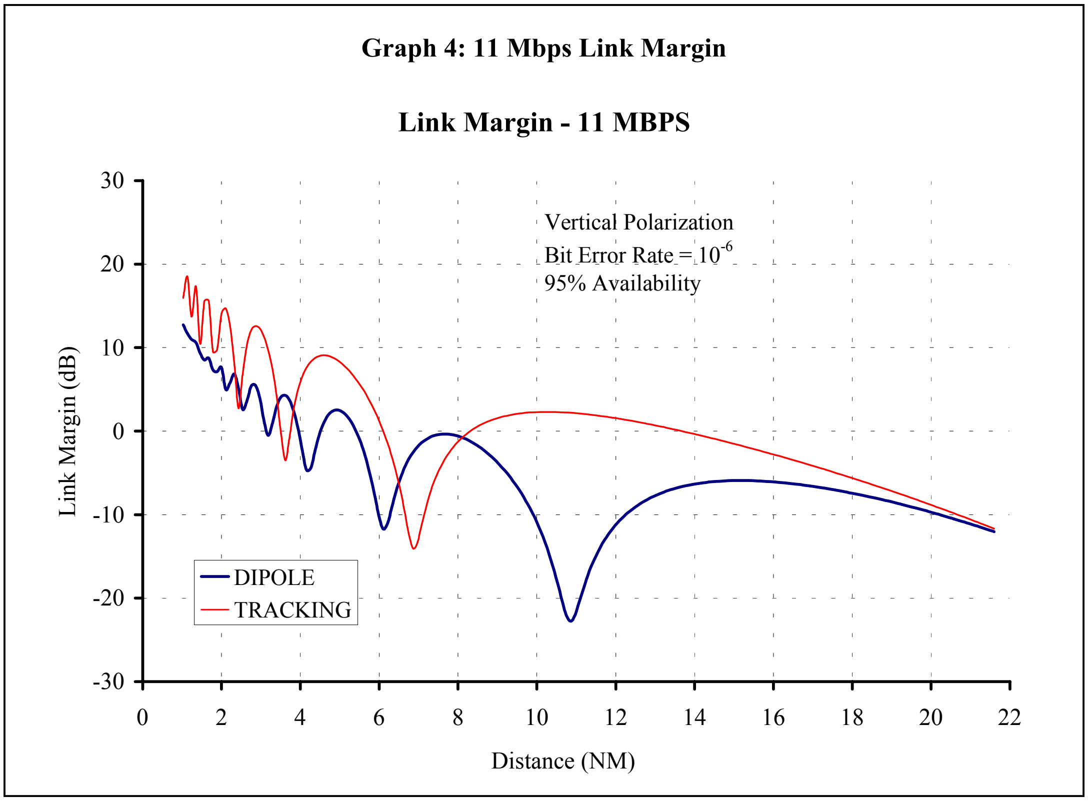
Link Budget

The quality indicator used to determine the digital link performance is called the link margin. The margin, expressed in dB, indicates the excess signal level available beyond that required achieving the desired bit error rate (BER), in this case, 1 in 10^6. The link margin is calculated by performing a link loss budget that provides an analysis of the signal starting at the transmit system, outward to the medium, and ending at the receive system. If each end of the link is not symmetrical in terms of the radiated antenna output power, data rate and receiver performance, then a separate link margin is calculated for each direction. The lower number indicates the available link margin of the system.

For the Neah Bay configuration, the link margin is calculated using the ship as the transmitter and the Federal Building as the receiver. Graphs 3 and 4 show the expected link margin for the 11 Mbps and 1 Mbps data link. The graph indicates that the tracking antenna predicted performance is better than the dipole between 8 and 12 NM while the dipole is better in the 6.5 to 8 NM ranges. The graphs show the expected link budget performance when the antenna height is constant, however perturbations of the antenna height by the sea motion causes movement in the nulls, which will proportionally affect the available link margin.

Graph 3: 1 Mbps Link Margin





Link Margin

Graphs 5 and 6 shows the link margin calculations for 11 and 1 Mbps data rates for 95% availability for three cases. In each case, the ship was assumed to be the transmitter and the shore-based system is the receiver. This assumption is based on the ship having approximately 4 dB less radiated transmit power than the shore site.

Cases 1 and 3 are the same with exception to the ship's antenna height is changed from 20 to 35 feet. This comparison indicates that the multipath null provides less of link degradation for the ship's antenna located at 20 feet instead of the 35 feet.

Cases 2 and 3 are the same with exception to the shore based antenna polarization is changed from vertical to circular. This comparison shows a 3 dB additional loss due to the mismatch of the antenna polarization between each end.

Case 1:
Ship Antenna
Height – 20 feet
Polarization is Circular
Gain – 15 dBi

Shore based Antenna
Height – 450 feet
Polarization is Circular
Gain – 19.2 dBi

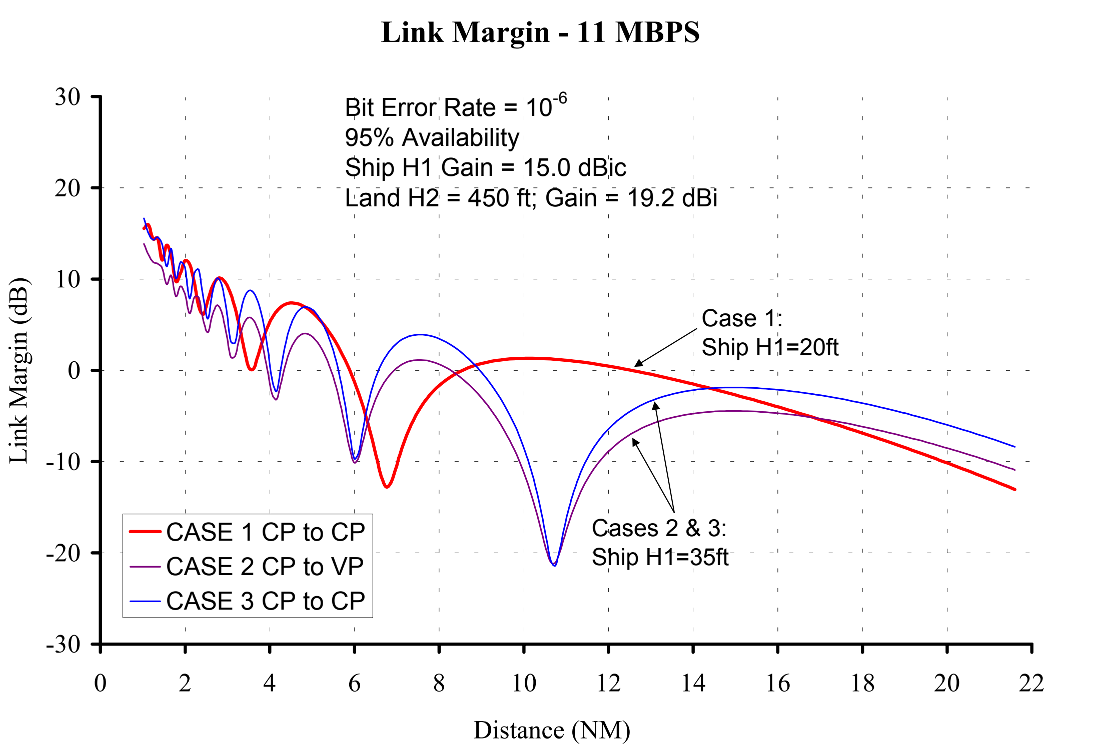
Case 2:
Ship Antenna
Height – 35 feet
Polarization is Circular
Gain – 15 dBi

Shore based Antenna
Height – 450 feet
Polarization is Vertical
Gain – 19.2 dBi

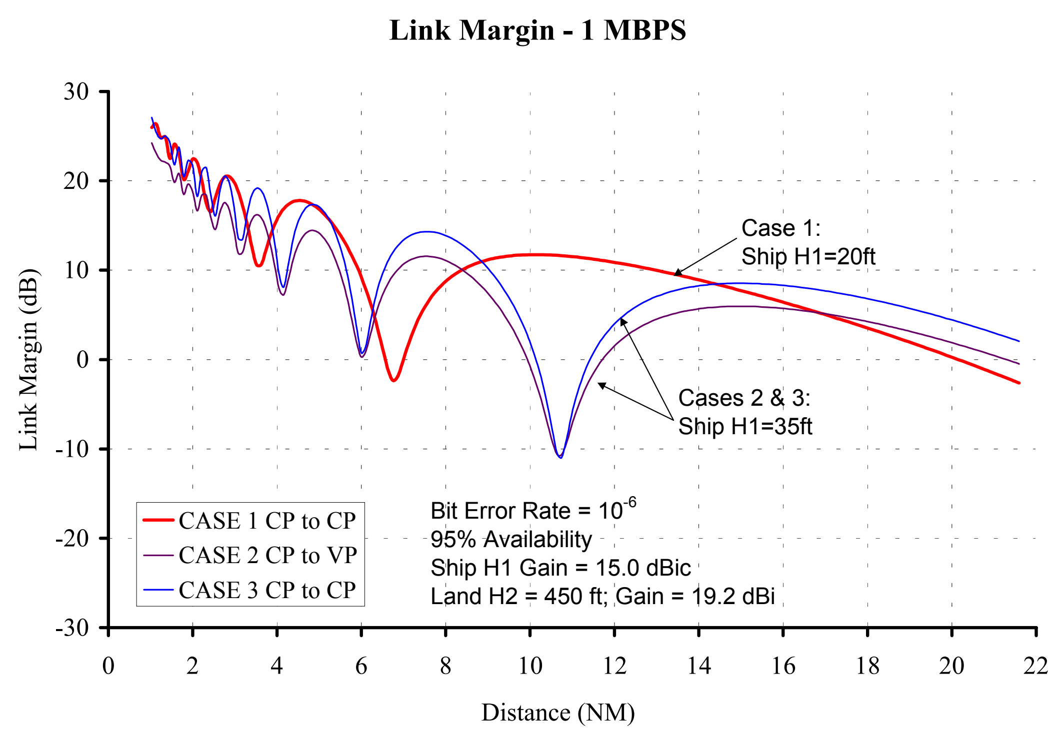
Case 3:
Ship Antenna
Height – 35 feet
Polarization is Circular
Gain – 15 dBi

Shore based Antenna
Height – 450 feet
Polarization is Circular
Gain – 19.2 dBi

Graph 5: Link Margin for 11 Mbps



Graph 6: Link Margin 1 Mbps



Recommendations

The above analyses shows if ship's antenna is placed at 20 feet instead of 35 feet it moves the location of null closer in and provides less link degradation. Although the null depth for a ship antenna mounted at 20 feet is not as great as when mounted at 35 feet, it still results in a negative link margin.

A method that helps to improve the link margin is antenna diversity. Most of the WLAN systems today utilize selection diversity schemes to minimize signal fading due to multipath. A diversity antenna system can be compared to a switch that selects one antenna or another, never both at the same time. The radio in receive mode will continually switch between antennas listening for a valid radio packet. After the beginning sync of a valid packet is heard, the radio will evaluate the sync signal of the packet, on one antenna, then switch to the other antenna and evaluate. Then the radio will select the best antenna, and use only that antenna for the remaining portion of that packet.

Implementation of the diversity at the shore based end helps to increase the level of the received signal. The placement of the twos antennas must be separated at least 10 wavelengths or 1.25 meters apart so that each antenna is in the farfield pattern of the other for proper diversity operation. The theoretical improvement using two antennas in a selection antenna diversity scheme is 7 dB for 95% link availability. The theoretical improvement assumes that the two signal paths are completely uncorrelated and the selection system operates on an instantaneous basis. The first requirement is controlled by the amount of antenna separation and the second is based on the speed of the selection process as compared to the reciprocal of the signal-fading rate.

Therefore, a practical selection diversity system may realize a 3 to 4 dB gain in link margin over a single antenna system. However, this is still a significant improvement when compared to the alternative methods for achieving the same link margin gain such as adding a larger antenna, RF amplifier or combination of both in the ship system.

Appendix

Cisco / Aironet Link Measurement Utilities

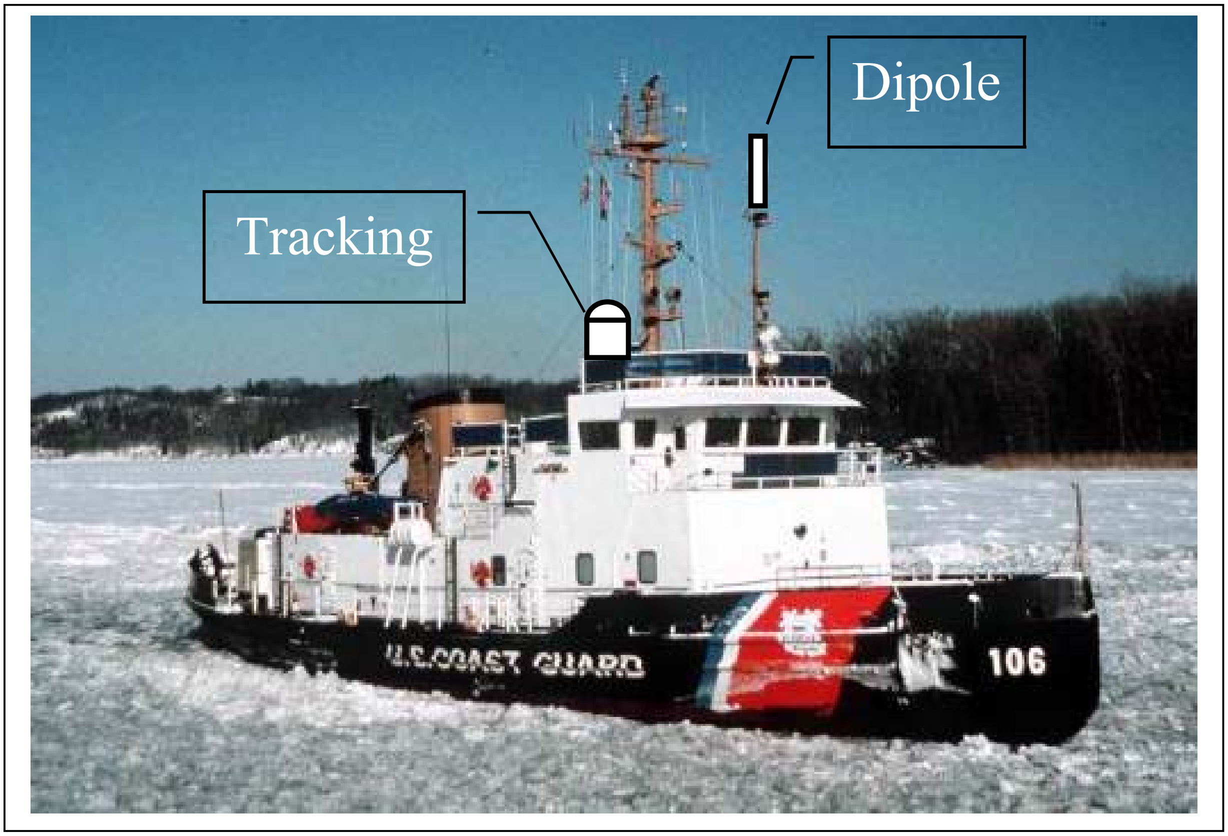
```
Aironet BR500E V8.07              SIGNAL LEVELS              MR_WB-2_b54r10

BR500E     00409656eac7 Strength  In ****************************************
                                 Out ****************************************
                         Quality  In *********************
                                 Out ********************
(^C to exit)                         |--------------------------------------|

Aironet BR500E V8.07              SIGNAL LEVELS              MR_WB-2_b54r10

BR500E     00409656eac7 Strength  In ****************************************
                                 Out ****************************************
                         Quality  In *************************
                                 Out **************
(^C to exit)                         |--------------------------------------|

Aironet BR500E V8.07              SIGNAL LEVELS              MR_WB-2_b54r10

BR500E     00409656eac7 Strength  In ****************************************
                                 Out ****************************************
                         Quality  In ************************
                                 Out ******************
(^C to exit)                         |--------------------------------------|
_
```

Figure 5 Link Signal Strength Test

```
Enter an option number or name, "=" main menu, <ESC> previous menu
>

Aironet BR500E V8.07          RADIO NODE STATISTICS             MR_WB-2_b54r10

 Id    Address     Signal    Tx Pkt     Tx Byte   Retry    Rx Pkt     Rx Byte Rate
--- ------------ ------- --------- ---------- ------- --------- ---------- ----
  1 00409656eac7  97/57       1459     391380      49      1351     377893   11

Enter space to redisplay, C[lear stats], q[uit] :
Aironet BR500E V8.07          RADIO NODE STATISTICS             MR_WB-2_b54r10

 Id    Address     Signal    Tx Pkt     Tx Byte   Retry    Rx Pkt     Rx Byte Rate
--- ------------ ------- --------- ---------- ------- --------- ---------- ----
  1 00409656eac7  97/55       1466     391898      49      1356     378253   11

Enter space to redisplay, C[lear stats], q[uit] :
Aironet BR500E V8.07          RADIO NODE STATISTICS             MR_WB-2_b54r10

 Id    Address     Signal    Tx Pkt     Tx Byte   Retry    Rx Pkt     Rx Byte Rate
--- ------------ ------- --------- ---------- ------- --------- ---------- ----
  1 00409656eac7  97/53       1472     392338      49      1361     378613   11

Enter space to redisplay, C[lear stats], q[uit] :
```

Figure 6 Radio Node Statistics

Antenna Locations



References

Outdoor Bridge Range Calculation Tool
http://www.cisco.com/warp/public/cc/pd/witc/ao340ap/prodlit/obrc_in.xls

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William D. Ivancic, David Stewart, Ken Edgein, Vincent Pansera, Terry Bell, Dan Shell, and Cecil Miller

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William D. Ivancic, NASA Glenn Research Center; David Stewart, Verizon, Cleveland, Ohio; Ken Edgein and Vincent Pansera, L-3 Communications, Camden, New Jersey; Terry Bell, Lockheed Martin Global Telecommunications, Cleveland, Ohio; Dan Shell, Cisco Systems, San Jose, California; and Cecil Miller, United States Coast Guard, Cleveland, Ohio. Responsible person, William D. Ivancic, organization code 5610, 216–433–3494.

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13. ABSTRACT ***(Maximum 200 words)***

The purpose of these tests was to determine the connectivity range and associated data rates for connection between the flat panel antennas on the Federal Building and the dipole and L-3 tracking antennas on the Neah Bay.

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