Antenna Modeling for Possible Co-Location of DGPS and Loran-C Signals

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Abstract

The United States Coast Guard is responsible for operating and maintaining the nation's two primary maritime radio navigation systems, Long-Range Navigation (LORAN-C) and Differential Global Positioning System (DGPS). The Department of Transportation has tasked the Coast Guard to expand the DGPS for coverage throughout the entire land surface of the United States. This enlarged system has been named the Nationwide Differential Global Positioning System (NDGPS). In an effort to save the Coast Guard, the Department of Transportation, and the U. S. Government significant costs, this project has investigated locating NDGPS transmitters at Loran-C transmitting stations. By creatively using the Loran-C transmitting antenna as a support structure for an NDGPS transmit antenna, the Radio Frequency Working Group (RFWG) believes that dual use of existing assets will permit these cost savings.

The emphasis of this project has been to investigate the feasibility of dual-use antenna configurations through computer modeling and field-testing. Three specific potential co-location antenna configurations have been researched, modeled, and simulated on the computer. One of these configurations was tested at the Coast Guard Loran Support Unit (LSU) in Wildwood, New Jersey. This presentation discusses the financial benefits of this effort, presents the antenna configurations investigated, and compares the results from the modeling effort and the field-testing.

Coupled with the results obtained to date, are suggested outlines for future work.

Introduction

The US Coast Guard is the lead agency for maritime navigation and as such is responsible for the nation’s two primary maritime navigation systems, Differential Global Positioning System (DGPS) and Long Range Navigation (LORAN-C). An initiative by the US Department of Transportation has been to install DGPS beacons on the interior of the country in an attempt to facilitate land based navigation with GPS called the National DGPS system (NGPS) (NAVCEN, 1). The US Coast Guard has been tasked with this initiative. Currently there are 126 sites planned in the NDGPS network with approximately 77 in place as of this writing (Wolfe, 2). The installation of new sites is extremely costly and the Coast Guard is looking for methods to reduce both installation and operating expenses of the NDGPS sites. One method being implemented utilizes US Air Force Ground Wave Emergency Network (GWEN) sites that are no longer in use (NAVCEN, 1). While the GWEN sites are saving tremendous amounts of money in the continental US there is currently no system in Alaska that can be similarly used.

The US Coast Guard Command and Control Engineering Center in cooperation with the US Coast Guard Academy has begun to look at the possibility of using current LORAN-C sites as potential broadcast sites for DGPS signals. The United States LORAN-C chain covers the entire continental US and Alaska. Many of these sites are in areas where there is poor or no DGPS coverage. By utilizing these sites the Coast Guard can fill in coverage holes in the NDGPS system at a minimal cost to the taxpayer. The greatest benefit will be observed in Alaska where there are multiple sites that can be utilized. This in combination with the extremely high cost of tower installation and maintenance in Alaska makes the prospects of co-location very valuable.

Background

For the past several years the US Coast Guard Academy has been modeling DGPS tower configurations in an attempt to increase the efficiency of the DGPS system nationwide. This modeling has been accomplished using power antenna modeling software called GNEC. When the idea of co-location surfaced the project's focus shifted to modeling potential methods of co-location. The Academy's responsibilities have centered around the creation and testing of two models, LSU and Carolina Beach LORAN-C station. The LSU model was completed in October '01 and testing of the design took place in late February '02. Testing reveled that the current configuration's efficiency was too low justify co-location. In April '02 an alternate configuration was created and is currently being tested. The Carolina Beach model was completed in April '02 and preliminary results have indicated co-location will be possible on four-tower sites.

Objective

The final goal of this project is to determine an efficient method of co-location for both single and four-tower arrays, while continuing to model current DGPS assets in an attempt to improve tower efficiencies. To meets these goals several short-term objectives have been met, however, a few remain unfinished. These center on determining an alternate efficient method for single-tower co-location and the testing of that method in a timely fashion. In conjunction with single-tower co-location, testing at four-tower sites needs to be examined more closely. These are necessary steps that must be taken in order to reach our final goals.

Technical Approach

Using measurements from LSU taken in August of this year we created a model of the Loran-C transmission site at LSU. Once completed, we added the DGPS modification into the model. This process took until mid October to complete. Shortly after, we began running tests on the model to determine impedance values and radiation patterns for the DGPS signal. In early November these results were sent to C2CEN. The preliminary testing at LSU was delayed until March due to problems in obtaining a testing frequency. While the preliminary testing was successful there were serious efficiency issues that came into play. We are now searching for ways to improve the overall efficiency of the system without changing the design too drastically. In parallel to the work on the testing site at LSU, we have continued to examine possibilities for transmitting DGPS signals at the four-tower Loran-C sites. Our latest design involves exciting one of the four towers as a DGPS antenna. Since these towers are electrically isolated from the

rest of the array we can use the entire length of the tower. Currently we have created a new ground system for the tower since the ground system of the array does not reach the towers.

Preliminary Results

To date we have completed two computer models of LSU with their modifications, (Figure 1,2,3) and the model of Carolina Beach. In Figure (1) the DGPS modification is the wire on the left side. The red indicates that there is conductive material, and as you can see the DGPS section is independent of the rest of the Loran-C tower. The space below the TLE's is where the supporting elements connect to the TLE's and the ground. However, they cannot be seen because they are not conductive and are not part of the system.

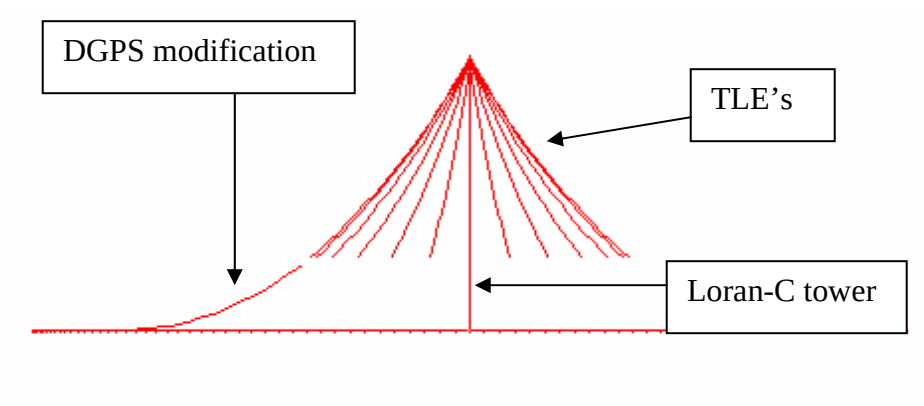

Figure 1: Original LSU model

Figure (2) shows the complete model from an offset overhead view. Here you can see the ground system of the Loran-C tower that extends 800 feet from the base. The DGPS system will be grounded to one of the ground wires within the system by digging down to it.

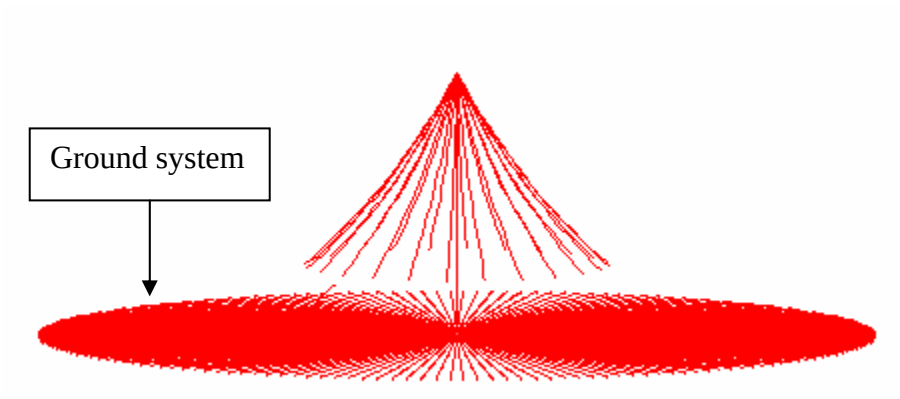

Figure 2: Second view of original LSU model

Figure (3) shows the new model LSU aimed at fixing the efficiency problems. This model involves moving the DGPS wire more parallel to the tower in order to increase the vertical gain of the antenna.

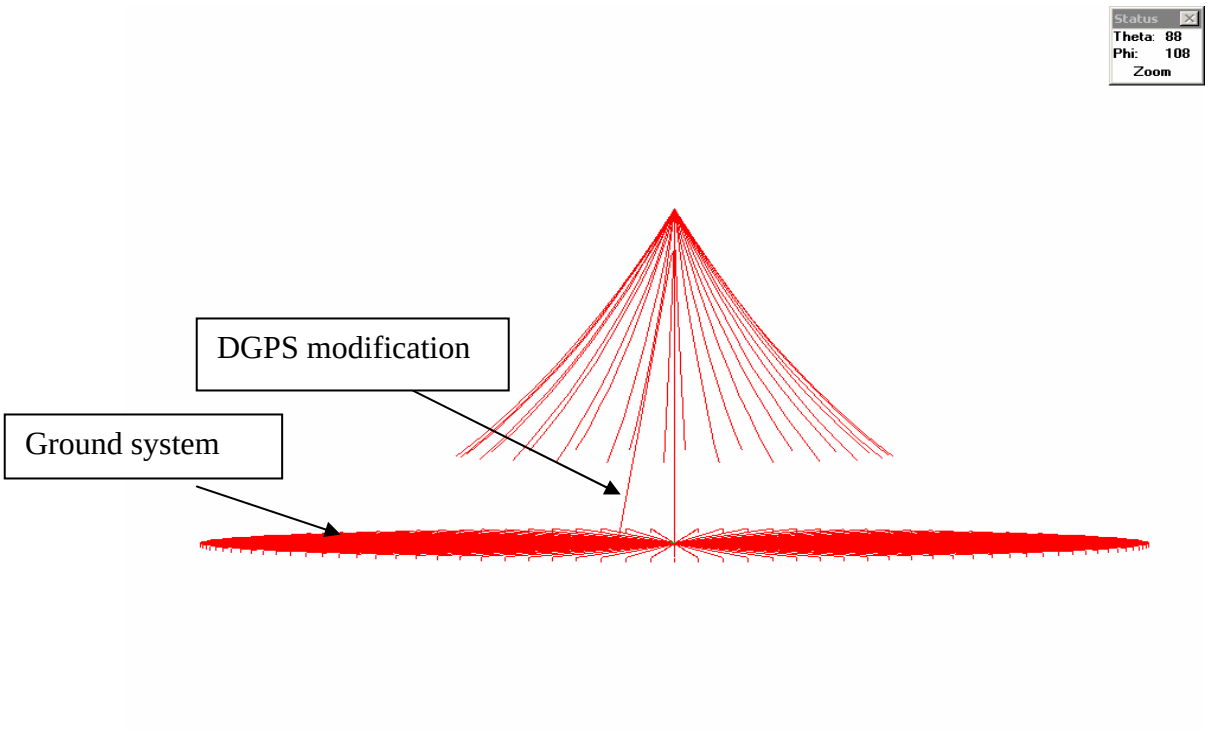

Figure 3: Updated model of LSU

The model of LSU has been used to determine possible radiation patterns (Figure 5) for the DGPS signal once transmission begins. The different colors on the figure indicate different angles, measured from the ground towards the tower, at which the radiation pattern has been measured.

Figure 5

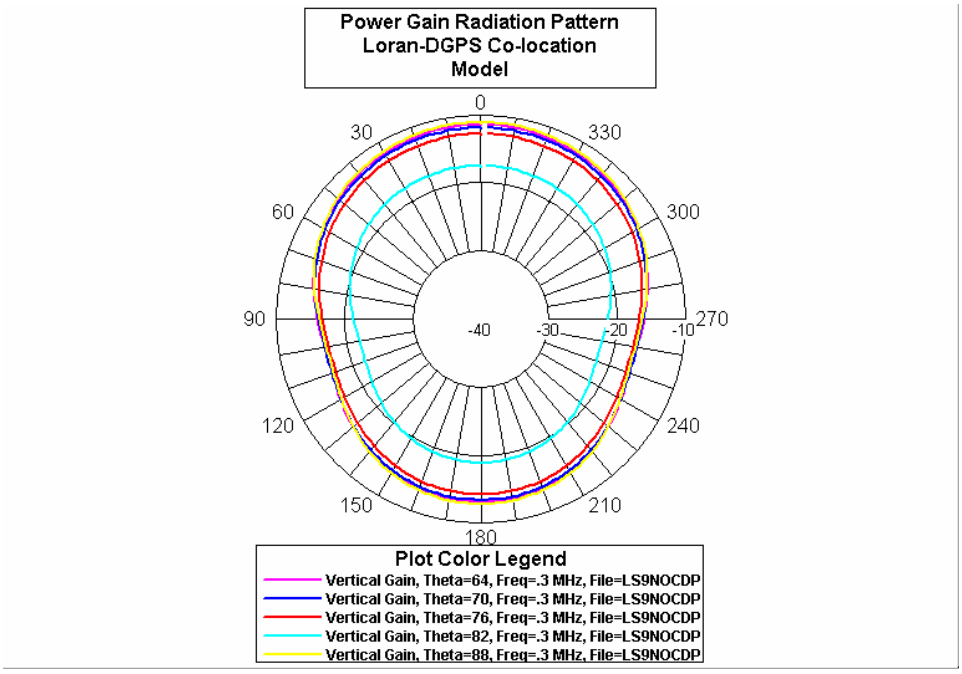

Figure (6) depicts the signal strengths obtained via aircraft during our testing at LSU. The plane flew in circles around the tower with radii of 2 miles and 10 miles. This picture proves that the pattern is at least moderately round, validating our model's results. Unfortunately the efficiency of the system was determine to be around 12% which was within 1% of the calculated efficiency on the model, further proving the validity of our model.

Figure 6: Signal strengths from LSU testing

In addition, impedance measurements for different frequencies have been determined and were used to design a filter network for the antenna coupler. The filter we designed based on theoretical numbers would reduce the transmission power of the mobile DGPS transmitter by fifty percent. Because of his we decided to omit the filter network during actual testing.

The Carolina Beach model can be seen in Figure (4). Here you can see the four towers and the ground system created for the transmit tower. The feed point for the tower has been connected at 50' increments going up the tower to examine impedance values. The values of these measurements are summarized in Table (1) below:

File Name	Feed height	R(dp) [Ohms]	X(dp) [Ohms]	P(in) [Watts]	Gain (dB)	P(rad) [Watts]	EFFICIENCY
MYCBCH01.NOU	50	68.768	130.569	15.78900	0.062172	0.981623	12.434
MYCBCH02.NOU	100	118.537	163.065	14.58340	0.117770	1.717490	23.554
MYCBCH03.NOU	150	207.373	196.893	12.68020	0.150557	1.909080	30.111
MYCBCH04.NOU	200	271.259	231.496	10.66500	0.168719	1.799390	33.744
MYCBCH05.NOU	250	348.447	269.945	8.96740	0.174069	1.560950	34.814
MYCBCH06.NOU	300	435.566	305.738	7.68970	0.179013	1.376560	35.803
MYCBCH07.NOU	350	535.163	329.228	6.77781	0.184536	1.250750	36.907
MYCBCH08.NOU	400	644.782	332.511	6.12553	0.190943	1.169630	38.189
MYCBCH09.NOU	450	757.700	307.493	5.66580	0.198081	1.122290	39.616
MYCBCH10.NOU	**500**	**938.455**	**340.498**	**5.32090**	**0.213825**	**1.137740**	**42.765**
MYCBCH11.NOU	550	935.406	159.822	5.19366	0.212491	1.103600	42.498

As you can see we have had the most success feeding the tower farthest from the ground. Another possible solution we came up with is attempting to feed the tower from the lowest supporting element, which is not electrically isolated from the tower.

Below, Figure (4), is a picture of the model at Carolina Beach with full ground system in place. The tower on the bottom left is the feed point for the DGPS signal. As you can see a separate ground system has been installed below the excited tower.

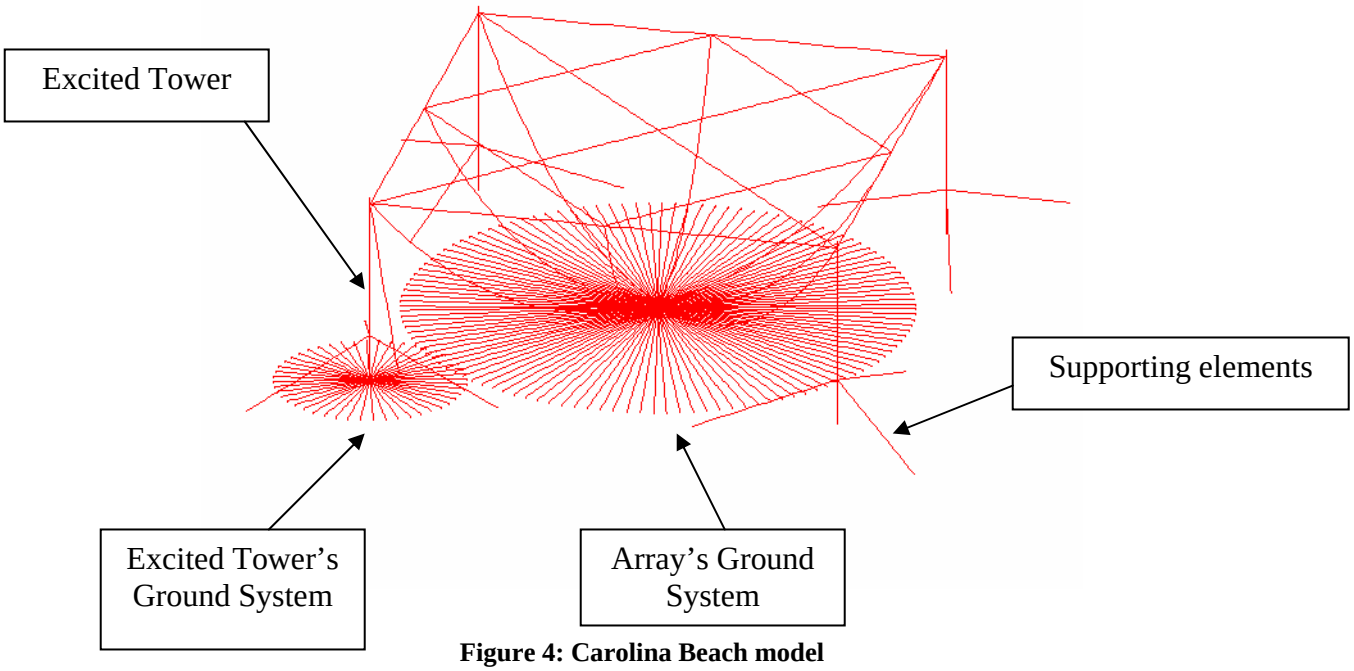

Figure 4: Carolina Beach model

Conclusions

To date we have finished models of both LSU and Carolina Beach. Preliminary testing at LSU has uncovered a serious efficiency problem in our co-location method in the single tower array, which has lead to work in resolving the issue. A more efficient method is being examined in conjunction with the testing on the Carolina Beach model. Next semester work will inevitably continue along these paths, in an attempt to work out co-location methods before all the DGPS beacons are installed and co-location will no longer be useful.

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