LORAN and DGPS Signal Coverage Software

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Abstract

The United States Coast Guard needs a more modern, and up to date coverage predicting software to replace its current program known as COAST. This paper outlines the senior design project which concentrated on taking previously developed software and putting it into a very user-friendly graphical user interface (GUI) form. MATLAB® GUIDE was utilized to provide for organized GUI building and fast implementation of the existing functions. The majority of the objectives for this year were met and the results were outstanding. All graphical user interfaces were linked and tested for functionality and performance. Additionally, tasks for next year will be based on the uncompleted work for this year and feedback from the Loran Support Unit as well as the Navigation Center.

Introduction

This has been an ongoing project concentrating on constant improvement and management of U.S. Coast Guard radio navigation. The sponsors of this project, Command and Control Engineering Center (C2CEN) and the Navigation Center (NAVCEN), have shown interest in creating a more up to date way of making signal coverage predictions for both Long Range Navigation (LORAN) and Differential Global Positioning System (DGPS) signals. The software program is a replacement for an older program known as COAST. The new program has a greater ability to theoretically estimate the coverage of individual transmitters throughout the United States. It models the effects of ground wave and sky wave propagation, as well as sky wave interference for antenna sites with the same operating frequency. This year's project will allow for easier and more functionality of the current software enabling the Coast Guard to see their overall coverage areas as well as better allocate resources for navigation.

Background

Prior development, done by Mike Danish ('00) [2], successfully created a software package that used Millington's Method of calculation [1] to allow the Coast Guard to estimate signal coverage of DGPS sites in the United States. It allows the user to visually analyze current coverage of DGPS and LORAN transmitters based on beacon parameter values for location, frequency and power. Prior to this year's work, the software provided lists of transmitter information selected through rough menus written in MATLAB® coding. Though thorough, all lists and menus were far from user friendly and were in need of up-to-date data and functionality.

Over the course of last semester, MATLAB®'s GUIDE program [3] was utilized to create graphical user interfaces to implement more user-friendly menus and functionality for the prediction software. The GUI's were linked to the original calculation functions much like the original program enabling the user to perform the coverage predictions more efficiently.

Objective

With the need for a more user-friendly software program, the scope of this project began with an implementation of a graphical user interface for the main menu of the program. Created in MATLAB®, the GUI would create links to the current software programming and provide a more organized and attractive program. In addition, updating the individual site parameters was necessary due to changes in power and frequency made over the past two years.

Additional tasks were to fix the continental borders of the United States, Canada, and Mexico as well as check accuracy of the coverage plots. Once these tasks have reached completion, the last objective is to prepare a prototype for submittal to NAVCEN and C2CEN.

Technical Approach

Necessary improvements were required in the functionality of the software and user-friendly operations of the program. The first step was to implement a Graphical User Interface using MATLAB® code to provide initial selection options. This GUI would provide all past options for the initial menu while giving a more attractive look to the software package. The MATLAB® GUIDE program was utilized for the layout and functionality that was necessary for this project. Using help files and specific reference material [3], GUIDE has proven very useful allowing quick creating of GUI layouts and providing callback functions for linking the GUI to the existing functions.

The necessary approach to building the GUI was to start small, eventually linking all the parts of the GUI together. Creating an interactive list box that allows the user to simply click on the selected beacon was the first small step. Once a selection is made, the plot functions will call on the existing coverage functions to produce graphs and other data based on the selected beacon. The project advanced by implementing up-to-date site data for more accurate coverage and was referenced from the NAVCEN information web site [4]. Once the information was obtained, updating the database of transmitters was necessary as well as testing of the data for the current coverage throughout the U.S. Current LORAN software still needs several improvements on the written code and functionality.

Results

The first stage of the project was to make the software program more user-friendly by implementing graphical user interfaces (GUI) for the different functions of the program. During the first semester, GUI functions for the list box, ground wave, and sky wave calculations were fully implemented to allow for easier accessibility and better organization than the original software package. These functions are selected through a main menu GUI (appendix 1) which makes every option the program has to offer, accessible using a computer mouse. During the second semester, emphasis was put on creating the beacon adding function and the beacon deletion functions. These functions are what allow the user to add possible future sites and see how the theoretical coverage will add to the total coverage of the United States. Additionally, the deletion function allows the user to delete any beacon they choose in the case where an antenna is actually removed from an old site. Lastly, once the graphical user interfaces were created for all of the programs functions, up-to-date beacon data was added. The original beacon data was used for the design of the program however, there are differences between the NAVCEN beacon parameters and the programs beacon parameters [4].

The idea behind the list box (appendix 2) is to be able to access the plot functions by simply clicking on the chosen beacon. The existing plotting function uses the beacon identification number as the key variable for finding the desired beacon information. Once the information is found, the ground/sky wave can be plotted for the user. However, the list box is simply a display of the BeaconList.mat file which is a preexisting character array. The beacon list array was divided up and set as two different arrays of information. One array simply listed the names of the beacons while the other listed the beacon identification numbers. The beacon ID numbers were then converted from a character array to a number array using the STR2NUM command. As a number array, each site is given an index numbers and can be easily accessed when necessary.

The ground wave GUI (appendix 3) displays a list of all information and data regarding every beacon. When a beacon is single clicked, the program will return the index number of the line where the click occurred. With the index number, the program opens the list of beacon identification numbers and finds the number with the matching index. This number is displayed in a text box so the user can see which beacon is the chosen one. Once the number has been entered and stored, the program calls the preexisting ground wave function from the original program. When the user compresses the plot command button on the GUI, the calculation process takes place. In a perfect world, the coverage around an antenna would form a perfect circle. However, due to the conductivity constants of the earth, the signal strengths over different terrains vary. The imbedded equations create strength values that take into consideration the different conductivities around the antenna. Once the calculations are made, the GUI will plot the site and show the effective coverage of the selected antenna (appendix 4).

The sky wave GUI (appendix 5) is very similar to that of the ground wave by way of displaying the data in a separate figure layouts in MATLAB®. The sky wave plot however, takes into consideration the sky wave produced by other beacons with the same frequency. Due to reflections of the ionosphere, the sky wave emitted from neighboring antennas with the same frequency causes distortions in the coverage plots. The sky wave plot shows the original coverage, without interference, as well as the sky wave and the coverage plot with distortion. The user simply selects a site from the list box of beacons. An additionally list box will then read the initial choice and load another list of beacons which are on the same frequency as the selected site. The user again will select a beacon with the same frequency from the second list box and hit plot to see how the two sites interact with each other (appendix 6). Additional options in the GUI are the ability to choose either median or worst case plots since the distortion from the ionosphere is worse during the night versus during the day.

As mentioned above, the second semester of the year consisted of implementation of the beacon addition function and the beacon deletion function. One of the main purposes of the software program is to allow for testing of the theoretical coverage for possible future sites. The addition GUI (appendix 7) allows the user to simply fill in the appropriate parameter values of the new site. These parameters include: beacon identification number, site name, latitude, longitude, frequency, and finally power. Once these fields are filled in, the user selects the “submit” button to enter the values into the database. If this site currently exists, an overwrite option is also available. The delete GUI (appendix 8) is the opposite of the addition GUI and is utilized for

updating the overall coverage of the United States. When sites are taken down or are no longer in service, the user simply has to click on the beacon site from the available list of sites, pulling up all the information on that specific site. Then when the user is ready to delete, he/she simply has to select to delete button to erase it from the database.

Conclusions

Overall, the project has been a success, fulfilling nearly every objective set forth at the start of the year. The majority of the years work has been spent using MATLAB®'s GUIDE program to create GUI's and link all major functions to newly created coverage software. All graphical user interfaces have been created and functionality is excellent. All GUI's are appealing to the user's eye as well as easily used by anyone. All that is left for the project is to complete the continental borders around Canada and Mexico. This is a major part of the program and was unfortunately not reached throughout this year's work. Additionally, continuation of updating the beacon database will also be necessary for next years work. Lastly, checking the coverage software against the COAST software located at NAVCEN must be completed for test of accuracy. Other than these few extra tasks, the project is successfully completed.

Appendices

Appendix 1: Main Menu Graphical User Interface
Appendix 2: Beacon List Graphical User Interface
Appendix 3: Ground Wave Plot Graphical User Interface
Appendix 4: Ground Wave Plotting Sample
Appendix 5: Sky Wave Plot Graphical User Interface
Appendix 6: Sky Wave Plotting Sample
Appendix 7: Add Beacon Site Graphical User Interface
Appendix 8: Delete Beacon Site Graphical User Interface

Works Cited

1. Commandant (G-NRN-3). *Procedures For Computing Loran-C Signal Strengths And Range Limits Using Millington's Method*. Washington, DC.: February 1986
2. Danish, Mike. *DGPS and Loran Coverage Software Paper*. United States Coast Guard Academy, New London CT.: Department of Electrical Engineering, 2000
3. Hanselman, Duane. *Mastering MATLAB® 6*. Upper Saddle River, NJ: Department of Electrical and Computer Engineering University of Maine, 2001
4. NAVCEN, U.S. Coast Guard. "DGPS Site Status." 2001 www.navcen.uscg.gov/ADO/DgpsSelectStatus.asp

Additional References

1. Cohoon, James P. *C++ Program Design*. McGraw-Hill Companies, Inc, 1999
2. Gambill, Burt. *Loran-C Signal Analysis Propagation Model Evaluation*. Washington, D.C.: National Technical Information Service, 1980
3. Mueller, Tysen. *Wide Area DGPS Design Issues Study*. Washington, D.C.: U.S. Coast Guard, Office of Engineering, Logistics, and Development, 1995

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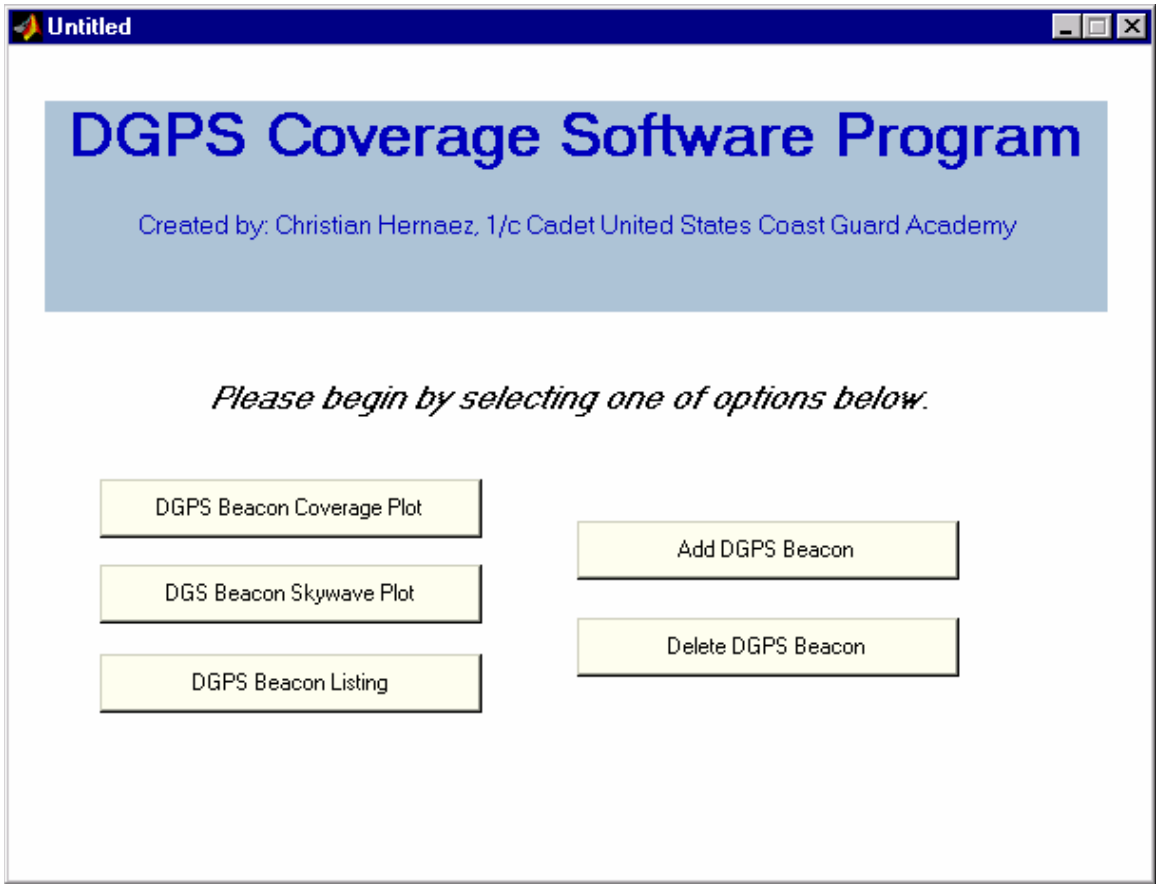
5. Peterson, Benjamin B. "Analysis of DGPS MSK Receivers in a Non-Gaussian Noise Environment" . New London, CT: Center for Advanced Studies, 1993
6. Peterson, Benjamin B. "Measurement of Loran-C Envelope to Cycle Difference in the FarField". New London, CT: Center for Advanced Studies, 1991
7. Popvic, Zoya. *Introductory Electromagnetics*. New Jersey: Prentice Hall, 2000

Appendix 1

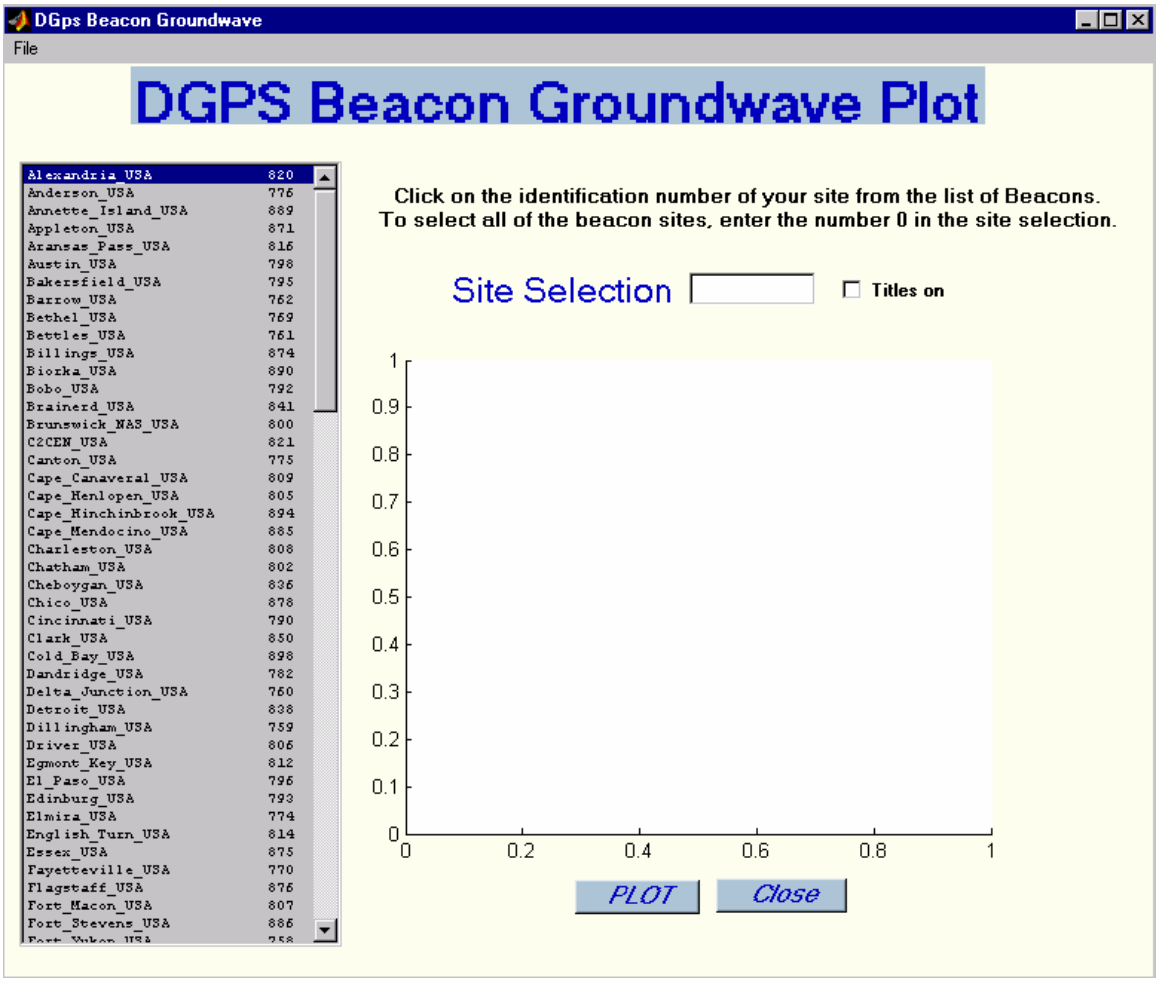
Main Menu Graphical User Interface



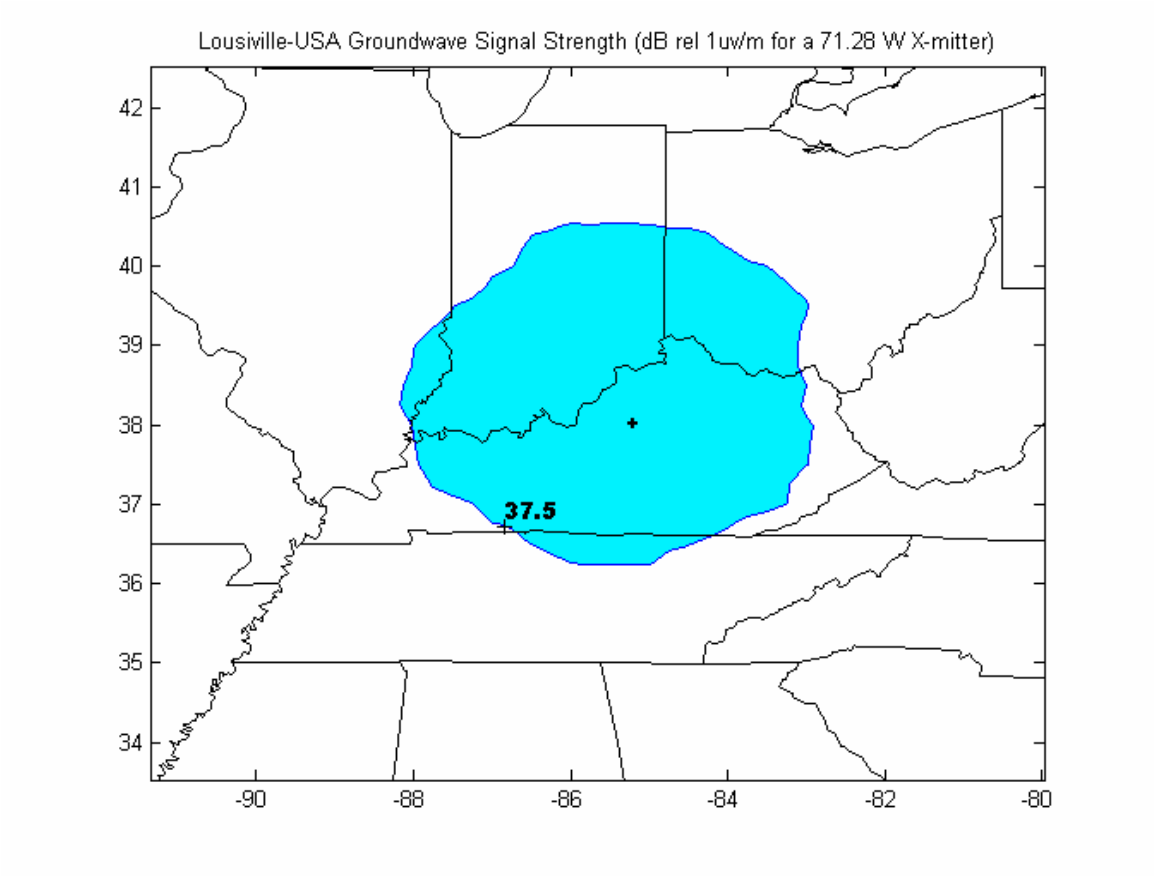
Beacon List Graphical User Interface

BEACON NAME	ID	LAT	LON	FRQ	EFF_PWR
Alexandria_USA	820	38.7533	77.1283	305	1
Anderson_USA	776	64.3	149.2	0	0
Annette_Island_USA	889	55.0583	131.6	323	170
Appleton_USA	871	45.7755	121.3205	300	1500
Aransas_Pass_USA	816	27.8383	97.0583	304	21.56
Austin_USA	798	39.39	117.3	312	0
Bakersfield_USA	795	35.13	119.1	305	0
Barrow_USA	762	71.2667	156.7833	0	0
Bethel_USA	769	60.8	161.7	0	0
Bettles_USA	761	66.9	151.5833	0	0
Billings_USA	874	45.9722	107.9963	313	300
Biorka_USA	890	56.855	135.5347	305	150
Bobo_USA	792	34.11	90.69	298	0
Brainerd_USA	841	46.61	94.0578	292	0
Brunswick_NAS_USA	800	43.89	69.9467	316	63
C2CEN_USA	821	36.868	76.3511	313	70
Canton_USA	775	36.07	98.59	0	0
Cape_Canaveral_USA	809	28.46	80.5433	289	69.65
Cape_Henlopen_USA	805	38.7767	75.0883	298	13.26
Cape_Hinchinbrook_USA	894	60.2383	146.6467	292	30
Cape_Mendocino_USA	885	40.44	124.4067	292	56
Charleston_USA	808	32.7567	79.8417	298	16.32
Chatham_USA	802	41.6717	69.95	325	10.375
Cheboygan_USA	836	45.6533	84.465	292	88
Chico_USA	878	39.43	121.6	318	512.5
Cincinnati_USA	790	39	85	294	0
Clark_USA	850	44.93	97.96	309	300
Cold_Bay_USA	898	55.0917	162.5317	289	170
Dandridge_USA	782	36.0203	83.3039	0	0
Delta_Junction_USA	760	64.15	145.75	0	0
Detroit_USA	838	42.2967	83.095	319	11.62
Dillingham_USA	759	59.0833	158.4167	0	0
Driver_USA	806	36.9583	76.5567	289	335
Egmont_Key_USA	812	27.6005	82.7608	312	62.72
El_Paso_USA	796	32	106.3333	316	0
Edinburg_USA	793	48.5585	97.7792	307	0
Elmira_USA	774	42.2343	76.8322	0	0
English_Turn_USA	814	29.8783	89.9417	293	38.57
Essex_USA	875	34.75	115.23	298	0
Fayetteville_USA	770	36.1912	93.9146	0	0
Flagstaff_USA	876	35.2197	111.8177	319	500
Fort_Macon_USA	807	34.6967	76.6833	294	7.95
Fort_Stevens_USA	886	46.205	123.9567	287	110
Fort_Yukon_USA	758	66.5667	145.2167	0	0
Galena_USA	757	64.7667	156.8667	0	0
Galveston_USA	815	29.33	94.7367	296	48.44
Glennallen_USA	756	62.2167	145.3667	0	0
Gooding_USA	857	43	115	320	0
Grady_USA	826	32.65	86.39	306	0
Great_Falls_USA	882	47.2	111.2	298	0

Groundwave Plot Graphical User Interface



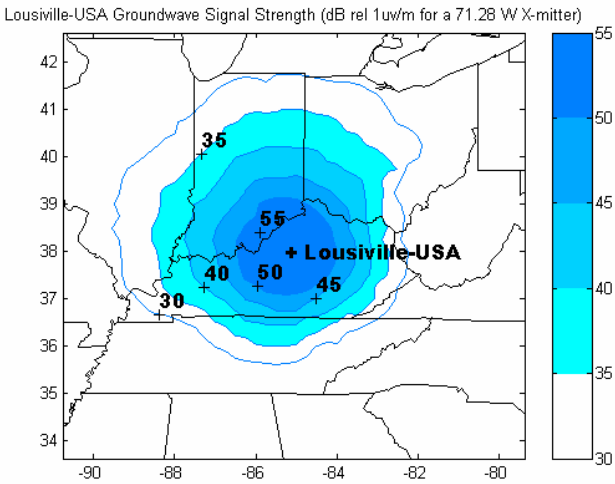
Ground Wave Plotting Sample

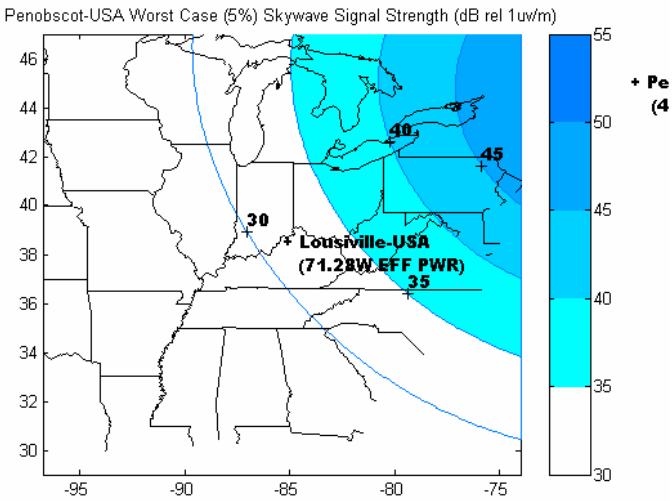


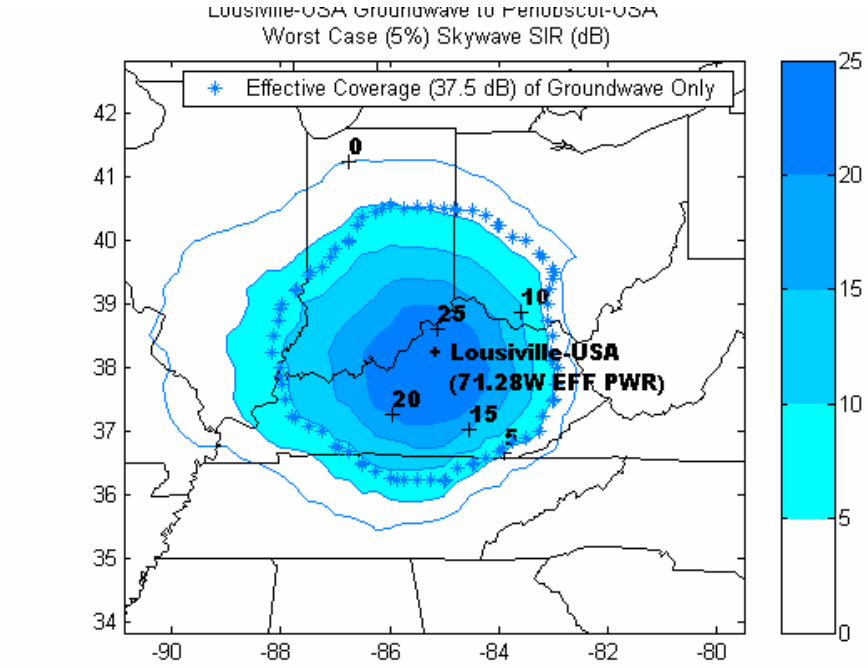
Appendix 5

Skywave Plot Graphical User Interface

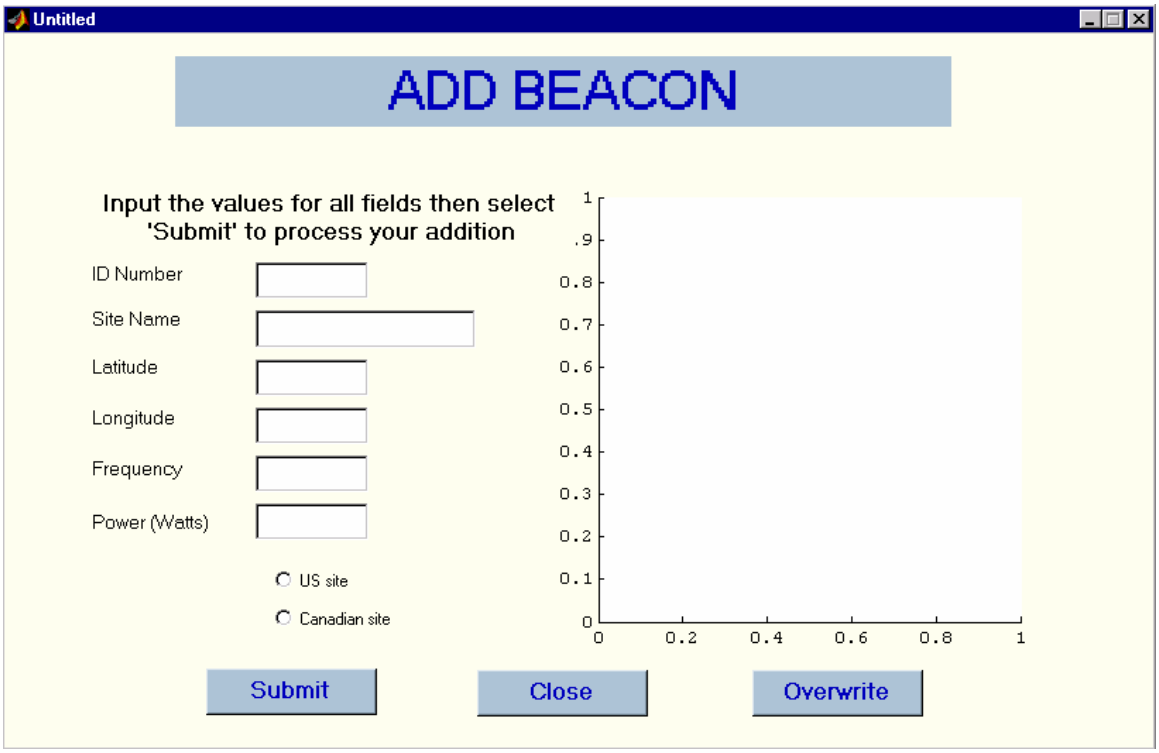
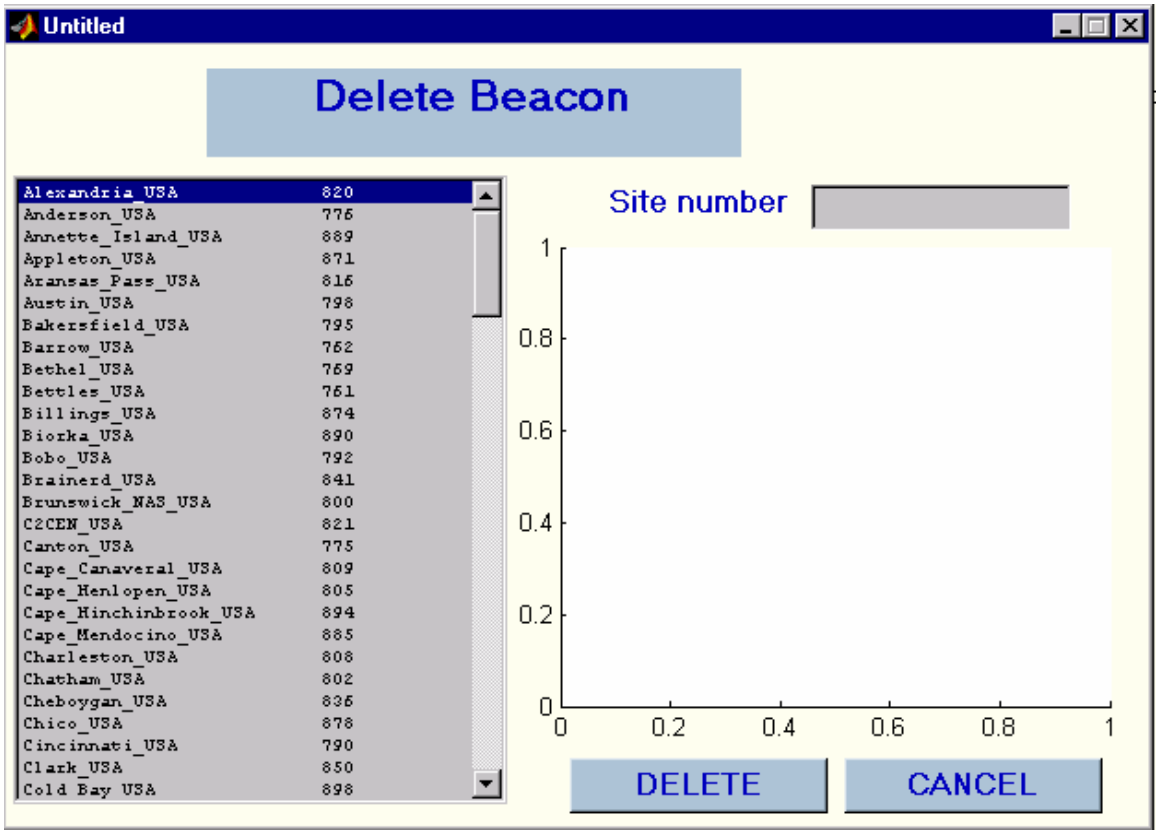
Skywave Plotting Sample







Add Beacon Site Graphical User Interface



Delete Beacon Site Graphical User Interface