DGPS Signal Strength Meter Project

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Abstract

Using digital signal processing, and existing research in radio spectrum frequency sampling, the concept of designing and building a directional signal strength meter for Differential Global Positioning System beacon transmitters was explored. Although the concept was not fully proven, the research and work completed indicate the concept is valid. Currently a large amount of the software and hardware framework components have been designed and initially tested. With further testing of the antenna array being used, and extensive field-testing to validate the software, proof of concept can be accomplished.

Introduction

The U.S. Coast Guard currently does not have the ability to validate propagation prediction models for Differential Global Positioning System (DGPS) beacon transmitters. This ability to validate a predicted coverage area is necessary in order to provide the mandated coverage required by the Nationwide Differential Global Positioning System (NDGPS).

Currently, a method to easily make directional field measurements of the signal strength radiated by a DGPS beacon transmitter does not exist. This results in having to use more resource intensive measurement techniques. The ability to quickly measure the signal strength of a transmission antenna has many more applications that just those associated with DGPS. Working in conjunction with the project sponsors, C2CEN and NAVCEN, the concept of a directional signal strength meter was explored.

Background

Although this project is essentially a proof of concept, it does rely on concepts already established in the Digital Very High Frequency (VHF) Direction Finding Program and the DGPS Antenna Beam Steering Project. In order to determine the signal strength of a DGPS beacon, it may be necessary to null out unwanted signals. This is where antenna array beam-steering concepts from prior year's projects are used. Using concepts from previous projects, along with implementation of additions DSP algorithms, directional measurement of DGPS beacon signal strength is possible.

Objective

This year, the primary focus was on proof of concept. Once the concept was validated, designing faster and more efficient algorithms to conduct the DSP were researched and implemented. In addition, one Graphical User Interface (GUI) package that would tie all the DSP, system control and data output to the user into one Graphical User Interface Package (GUI) was considered a primary goal of the project. The end objective was to produce a portable computer-based directional signal strength meter and signal analysis package for Differential GPS beacons.

Technical Approach

This project is both hardware and software intensive. In order to process all the raw data at an initially desired sampling rate of 800kHz, a computer with a high-speed processor and a fairly large amount of RAM is needed. In addition, high-speed analog to digital converters will need to be employed. This, in conjunction with a mini-loop antenna array, RF bandpass filters and pre-amplifiers comprise the hardware component of the project. The remainder of the project is essentially software and DSP algorithm development. MATLAB© will be used exclusively for the proof of concept. The primary reason for selection of MATLAB© as the software language was the ability to make rapid changes to the software code, without the need for recompiling as with other languages. Future enhancements may lead to converting the software over to C++ or other languages.

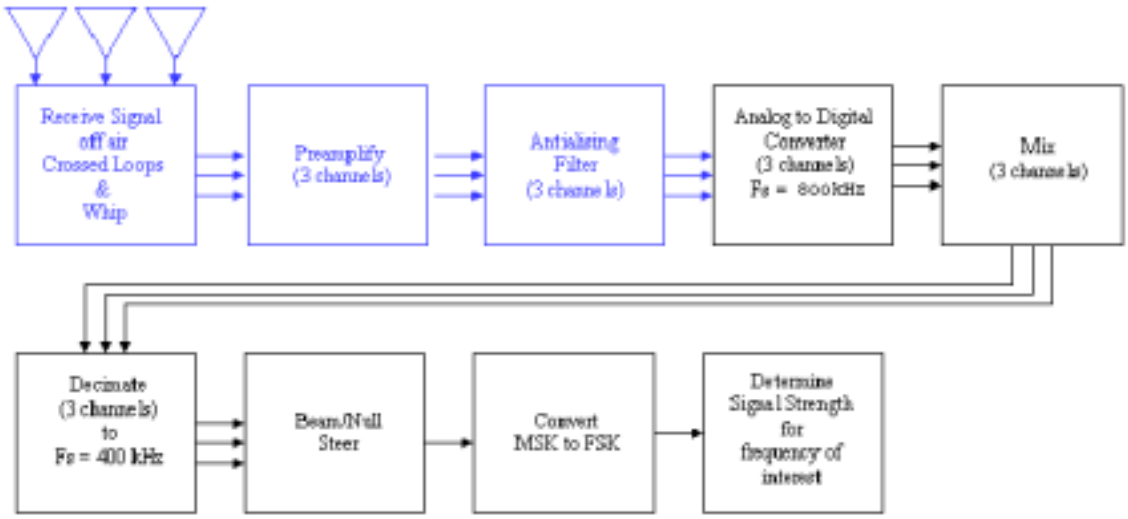


Figure 1 - Directional DGPS Signal Strength Meter System Block Diagram

Figure 1 outlines the general block processing approach to the signal strength meter. The first step in the data collection and processing is to bring the data in from the loop antenna array, pre-amplify it, filter it, and then sample the data at 800kHz. Once the data is sampled, the preliminary DSP approach is to band-pass filter the data, mix directly down to base-band after applying a Hilbert transform, decimate the data to ½ its original sampling frequency, and then

implement beam/null steering algorithms. From this, the signal strength of the DGPS beacon of interest can be obtained by using either an FFT or Matched Filter.

Results

Software

Figure 2 – Primary

Results in software development for the project have included GUI design and coding, signal processing algorithms and coding for hardware/software interfaces. The data from the three separate antenna channels is brought into the MATLAB© environment, filtered, mixed and decimated prior to applying the beam steering equations and signal demodulation.

The entire software package is GUI driven to allow for ease of system configuration and data display to the user. Figure 2 illustrates the main menu of the software, allowing the user to access any part of the software package. Initial setup (i.e. DGPS beacon of interest and user's geographical location) and complete system configuration (i.e. sampling time and number of sample iterations) is accomplished via the GUI illustrated in Figure 3. In addition, another system configuration GUI, shown in Figure 4 allows the user to customize more specific parameters within the software (such as antenna, DSP and filter gains, sampling frequency and digital bandpass filter specifications). This, in conjunction with the other configuration options, allows the user to change any configuration as conditions dictate, and work with the sampled data, all from one interface.

Figure 3 – System Data Recording Configuration GUI

An example of the data display GUI is illustrated in Figure 5. The display gives the user access to a wide range of information regarding the signal of interest, and the ability to save the data, or change the system configuration.

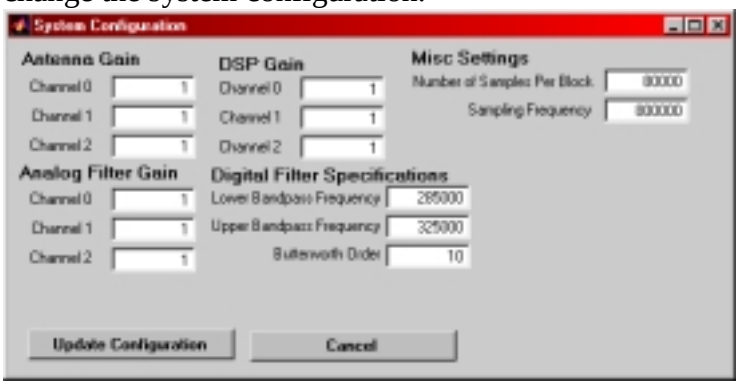


Figure 4 – System Configuration GUI

During the course of the project, it was determined that the biggest performance bottleneck was processor speed and available memory. Although a Pentium III 1GHz processor was being used, along with 512 MB of RAM, processing time samples greater than 0.1 seconds was requiring approximately 5 to 10 minutes at the initial desired sampling rate of 1.6MHz (to provide for less expensive RF filters). A faster processing time was needed in order to process longer time samples. In order to provide a faster DSP algorithm, it was necessary to reduce the sampling frequency to 800 kHz.

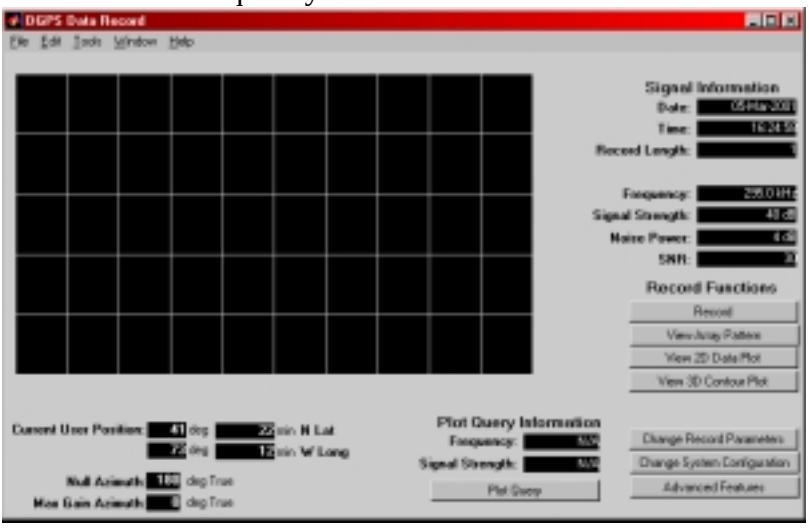


Figure 5 – System Data Display GUI

Difficulties were encountered with determining an algorithm to execute the entire sampling, and DSP process, while still remaining flexible enough to allow for a variety of recording methods. Currently, the software samples 3 input channels on the Analog to Digital conversion board, filters the data, then mixes it down to a user-specified center frequency, and decimates it. The algorithm to determine the signal strength of an MSK DGPS beacon signal has not been implemented, due to lack of necessary hardware.

Hardware

One of the first things that was looked at were the crossed loop antennas that would be receiving the DGPS signal. Initially, the field patterns for the two loop antennas were obtained using an HP89410 vector analyzerIN order to verify performance of the crossed loop antenna, particularly relative gain characteristics, data was recorded and plotted in MATLAB©- these field patterns are shown in figures (6) and (7).

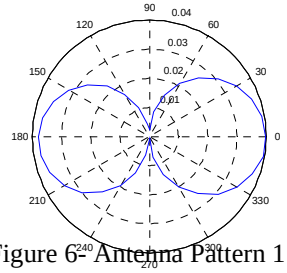


Figure 6- Antenna Pattern 1 (HP 89410)

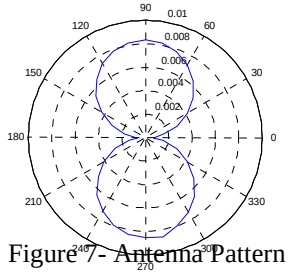


Figure 7- Antenna Pattern 2 (HP 89410)

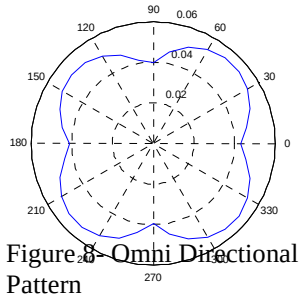


Figure 8- Omni Directional Pattern

After the individual patterns were examined, an idea to combine the two loops to produce an omni-directional pattern was explored. This was explored because of the possiblity of implimentation with out the use of the whip antenna. It was seen that only a cloverleaf pattern could be obtained, and not a circle. (Figure 8).

After the antenna patterns were analyzed, the signals from the antennas were sent through SRS SR-560 Low Noise Preamplifiers. These were used to amplify the signal and provide some broad band pass filtering before sending it into the NuDAQ board. The NuDAQ PCI-9812 20 MHz High Speed Analog Input Card was used to digitize the signal from the antenna into the computer through the use of MATLAB©.

Coding for the implementation of the NuDAQ board was obtained from the Digital VHF Direction Finding Project. Once the board could be initialized with the coding provided, it needed to be shown that the signal from the antennas were actually making it into the MATLAB© environment.

As seen in Figure 9, the signal was read in, and plotted as if it were being displayed on the 89410-vector signal analyzer giving the frequency of each signal on a log based y-scale. There are three graphs total, one from each antenna used. In later stages of testing, we were sampling at 0.8MHz and were looking at an x-axis of 0 - $4X10^5$Hz.

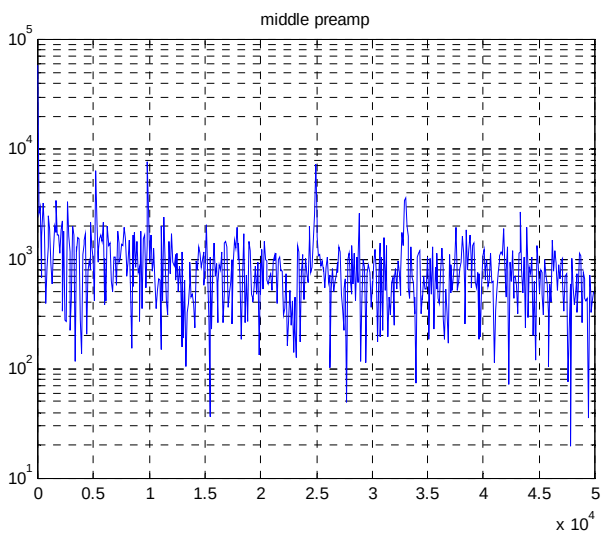


Figure 9- Plot from MATLAB© X-axis in HZ
Y-axis represents signal strength

After looking at the characteristics of the antennas, they needed to be field-tested. The three antennas were taken out into the field to be compared with a calibrated antenna. While in the field, only one out of the three antennas worked. When taken back to the lab for repairs, they started to work again when analyzed with the HP89410. There is no explanation on why the antennas were not working out in the field, and why they started to work again in the lab. After further reflecting on the unstable workings of the antennas being used, it was determined another array would need to be procured.

At this point, there were two areas that needed to be worked on to complete the hardware side of the project. These were the physical band pass filters and the antennas. The antennas that are now being used are KA 44B model antennas made by Allied Signal Company. These are crossed loop antennas that will be used for beam steering. The antennas were received from another project and alterations were made for compatibility with this project.

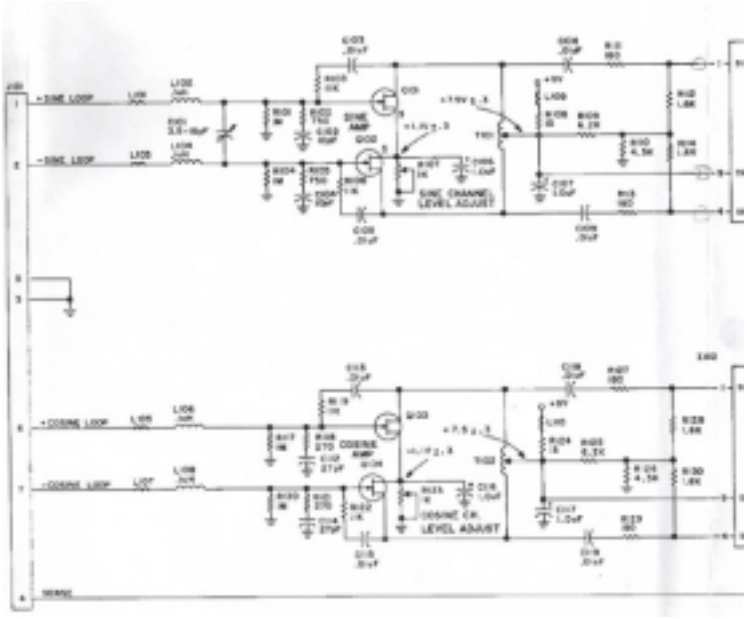


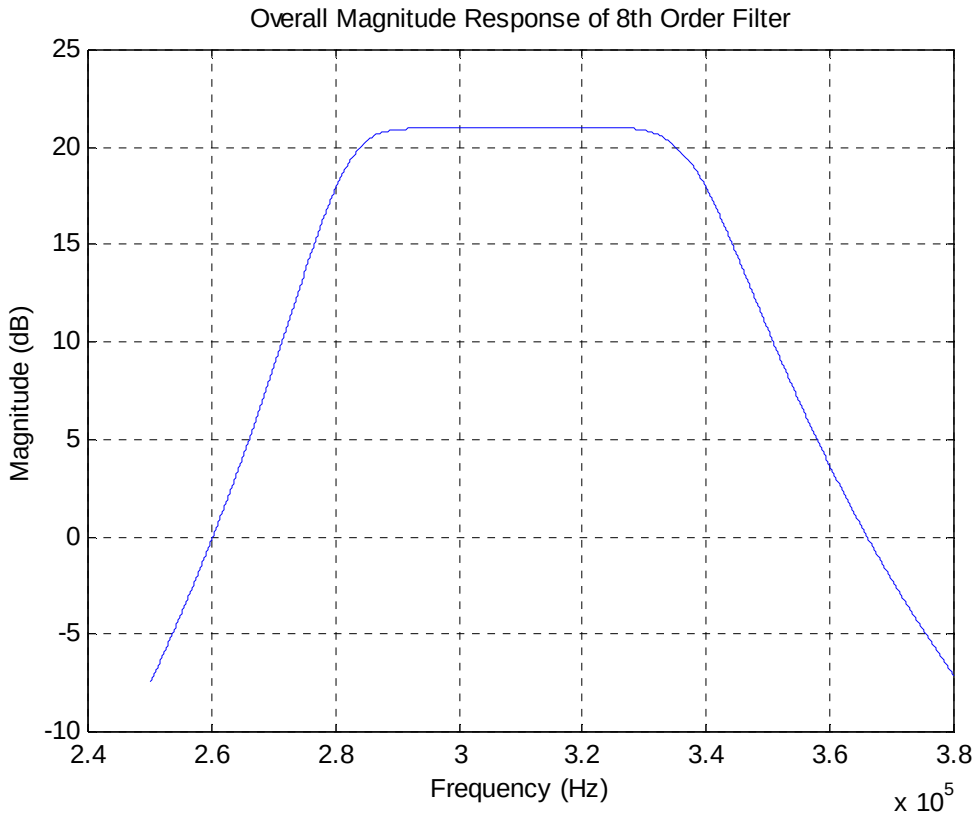
Figure 10- First circuit board of the 44B antenna

The piece of ferrite with the coiled loops of wire around it was kept as the receiving part of the antenna itself. This was then run into the first circuit board from the 44B (Figure 10), that put the crossed (cosine and sine) loops of the antenna through an amplifier. The vector signal analyzer was applied to the circuit at this point to see what signals the antennas were picking up. It was seen that DGPS signals were indeed being received.

The next step will be to sum the two coils for each loop; so the result will be one output for each loop. This may possibly be done with two of the second circuit boards that were also provided with the original antenna. On the second circuit board there is a transformer that will sum the two coils of one loop together and produce an RF signal that is Hi and Low with respect to ground. After this is done, testing will need to be done to determine what the overall gain of the antenna is before sending it into the band pass filter.

The second part of the hardware portion of the receiver was to look at developing a hardware band pass filter to attenuate any signals outside of the 283-325 KHz band range before sampling. Research was conducted to determine who could provide an 8th order band pass filter that would meet our specifications. Instead of having the band pass filter designed and constructed by a third party, the Linear Technology LTC1562-2 chip was considered. This chip provided four-second order sections capable of producing an 8th order band pass response. By utilizing manufacurer provided design equations to determine resistor and capacitor values, we were able to create a band pass filter with close to the desired response. The filter was designed according to the following specifications: Pass band of 285-325kHz, Stop band of 165 and 425kHz, Pass band gain of 0db, and a Stop band attenuation of 60db.

The results of the desing equations were implemented, frequency response measured, and components adjusted to provide the final response shown in figure (11).



Conclusion

Due to extensive time spent with obtaining operational antennas, proof of concept was not completed. Although with the data obtained, the concept appears to be valid and its implementation possible. Although the receiver is not complete, a large amount of the software and hardware framework has been completed and initially tested. Once the antennas are modeled within the software (for directional gains), and the array is coupled with software, extensive field testing will need to be completed in order to validate the software package. With this complete, proof of concept can be accomplished

References

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