AcousticShield DESIGNS

April 20, 2005

Mr. Lakshman One
School of Engineering
Science Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 440 Post Mortem Report for Acoustic Shield Designs project

Dear Mr. One:

Attached you will find the *AcousticShield Designs' Post Mortem Report* for an Electronic Counter Sniper System. This document lists the results and conclusions of our ENSC 440 project.

AcousticShield Designs designed and implemented a system that would aid military and law enforcement personnel in quickly and accurately locating the origin of a gunshot.

This document compares our initial assessment in terms of design, budget and scheduling to the finished project specifications. AcousticShield is an ENSC440 project group, consisting of one fourth year and three fifth year students: Marko Gasic, Sandeep Brar, Balraj Mattu, and Ehsan Dallalzadeh. If you have any concerns or questions regarding this proposal, please contact me by email or by telephone at 604 340-8603.

Sincerely,

Marko Gasic

Marko Gasic,
President and CEO
AcousticShield Designs

Enclosure: *Post Mortem for an Electronic Counter Sniper System Design*

AcousticShield DESIGNS

Post Mortem for

Acoustic Counter Sniper System

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Issued Date: April 20, 2005

EXECUTIVE SUMMARY

AcousticShield designed and developed an Electronic Counter Sniper (ECS) system that uses the acoustic response of a gunshot to identify the precise location of the shooter immediately after the shot is taken. By denying the shooter anonymity and enabling quick and accurate localization, our system could enable military and law enforcement personnel to quickly and effectively locate and respond to such attacks. By making a response much more likely and effective, we believe that our system will act as a significant deterrent in prevent these types of attacks in the first place.

With this document, AcousticShield presents a summary of the finished design and outlines the ECS system described above. Our group consists of 3 fifth year and one fourth year engineering science students with skills in systems integration and programming that were essential in making this project a reality. We examine our budget and schedule and compare it to our initial goals and estimates.

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1. Introduction

The purpose of this document is to present a post mortem summary of results for the Electronic Counter Sniper.

The purpose for the Electronic Counter Sniper device is to accurately detect the acoustic signature of a gunshot and to locate the origin of the shot within seconds of the event.

The task of developing this device was divided into three stages: the signal retrieval stage, the signal processing stage, and finally the user output stage.

1.1 Glossary

***A/D*:** Analog to digital

ECS: Electronic Counter Sniper

CCD: Charged Coupled Device

DSP: Digital Signal Processing

PC: Personal Computer

GUI: Graphical User Interface

1.2 Intended Audience

This document is intended to be a design guideline for the designers and engineers within *AcousticShield.* Its intention serves as ensuring that the product developed by *AcousticShield* meets the specified requirements for appropriate production.

2. Current State of the Device

As demonstrated in our group presentation on April 12, 2005, the Acoustic Shield ECS system is functional and operating within design specifications. The system is able to distinguish between the designated sample gunshot and deviant sounds. The system fails to make a distinction for sounds that bare similar low frequency characteristics as the sample gunshot. The system is also designed not to respond to sounds below a specified amplitude threshold, thereby eliminating much ambient noise such as regular conversation from causing false triggers. Once a sound has been identified as a gunshot, our system can determine the direction of the origin of such sound to within a 3º cone in space with a very high repeatability, 100% repeatability according to our testing.

Even though our final system deviated from the design specifications, we feel that we accomplished our task successfully in that we were able to meet the design specifications introduced earlier in the course. We also had the opportunity to carry out system testing that verified our performance specifications and allowed us to detect and subsequently correct some minor bugs in the system. Unfortunately, it was not possible to design a production ready system in a period of 4 months and very limited funding. This system should be regarded as proof of concept and should it be decided to take this system further in a development path, additional time, funding and prototypes would be required.

In subsequent sections we present specific subsystems and compare them to the initial design specifications as well as offer some reasons for any deviances between the two. We also present some ideas and suggestions that would be beneficial to implement in a future iteration of the ECS system.

3. Deviation from Design Specification

3.1 Data Acquisition

As per design specifications, the microphones used in the project are omni directional electret condenser microphones. We used electret style microphones for the following factors:

a) Low Price – at 2$ per microphone, they were the most affordable
b) Linear Frequency response for all desired frequencies (20Hz-20kHz)
c) Omni-directional – near uniform sound pickup from all directions

Figure 1 is a typical electret microphone response curve supplied for Panasonic electret microphones; note the high degree of linearity in the region of interest.

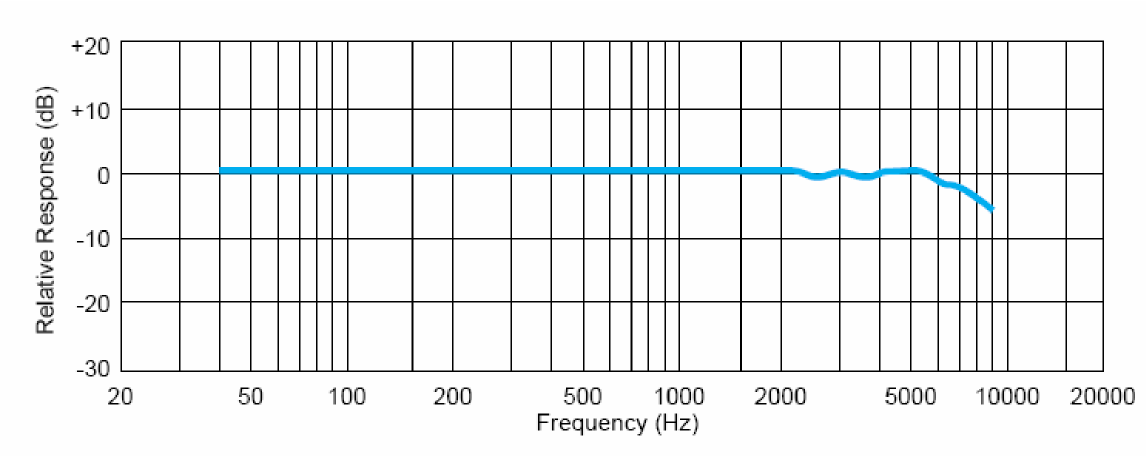

Figure 1: Electret Response Curve

A standard electret microphone unbalanced preamplifier with phantom power was used. Due to economic reasons, we bought the pre amplifier from RP electronics, at 10$/ pre amplifier, this was much less costly than purchasing the components and custom fabricating PCB's. The pre amplifies provide a +/-500mv output that was compatible with standard PC Soundcard microphone unbalanced input.

The 4 signals were acquired using the M-Audio Delta 44 professional PCI audio card. Delta 44 provides 4 analog inputs at 24bits with a sampling rate of 8 kHz-96 kHz. The sound card provides Windows XP drivers which allowed us to seamlessly integrate the card with the operating system and Matlab data acquisition toolbox.

Using the Delta 44 as our signal acquisition method deviated significantly from the earlier proposed Texas Instruments DSP kit, TMSC320C6711. After acquiring the TI PCM3003 Audio Daughter card, which we thought would allow us to sample up to 4 separate inputs, we discovered that the function of the daughter card is to replace the existing low quality codec supplied with the DSP kit, and therefore, the additional card would be the only means of input, with only two analog mono signals sampled. Certainly 2 signals ware completely inadequate for 3D triangulation and this was a clear factor in deciding to discontinue development using the TI DSP. Other factors that complicated development with the TI DSP included incompatibility with the available version of Matlab as well as Code Composer 3.0 incompatibility with the C6711 DSK.

3.2 Data Processing

As described above, the elimination of the TI C6711 DSK precluded its use as our primary signal processor. The signal processing task was implemented on a PC based on the AMD Athlon XP processor and Microsoft WindowsXP. The recognition algorithm was implemented in such a manner that incoming signal was rejected until signal level at input exceeds 0.2V threshold. Only after exceeding this limit, a 1 second clip of sound was recorded and processed to determine weather it was a mach for the gunshot. This eliminated the need for real time processing of the signal and the use of a DSP processor was no longer necessary.

The gunshot detection algorithm itself was modified from that described in the design specification. Instead of performing a continuous FFT on the incoming signal and matching to a pre defined envelope, the method employed was to calculate a power spectrum of the entire 1 second buffer, generated following a threshold trigger. Once the power spectrum was generated, the power ratio of 2 characteristic frequency ranges was compared. If this ratio was found to be consistent with a gunshot, a positive match was returned. Figure 2 shows a sample power spectrum of a gunshot sound, the frequency ranges considered are from 100Hz to 400Hz vs. 1250Hz to 1750Hz.

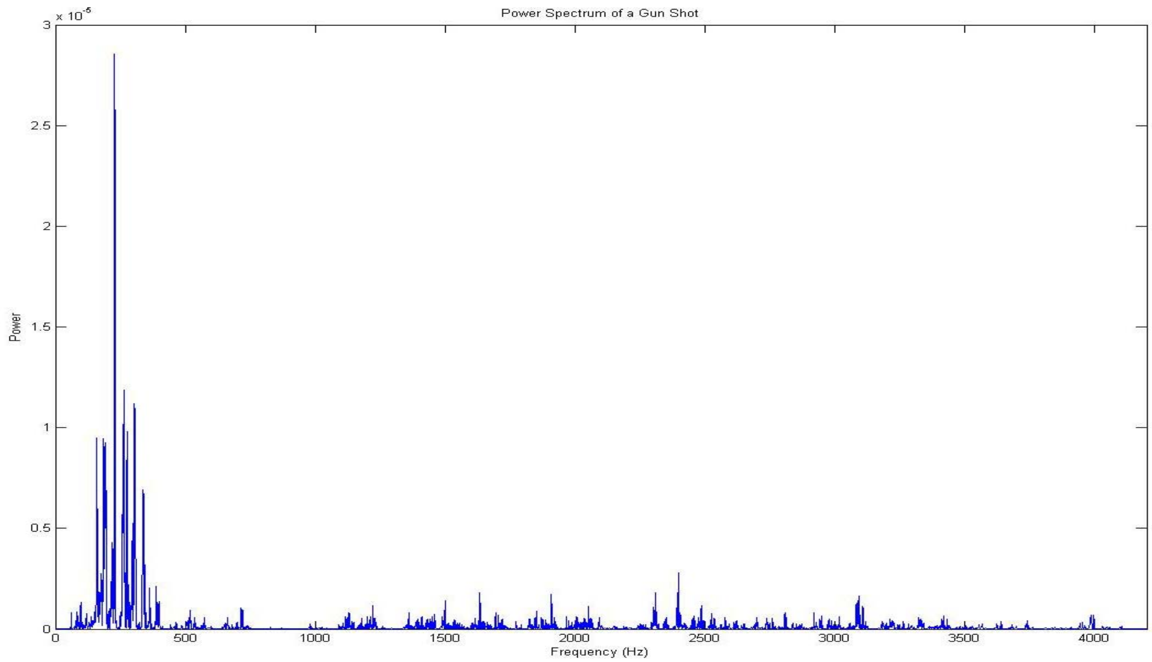

Figure 2: Sample power spectrum

Once a signal was determined to be that of a gunshot, a normalized cross correlation algorithm was run on the 4 input channels to determine the time domain phase shift in the signal, and thus extract the time delay subsequently used to triangulate the origin of incident sound. Figure 3 shows the initial stages of a gunshot wave profile, it is clearly visible that the 4 channels follow a similar pattern but are clearly out of phase. This similarity in signal shape allowed the cross correlation algorithm to be highly successful.

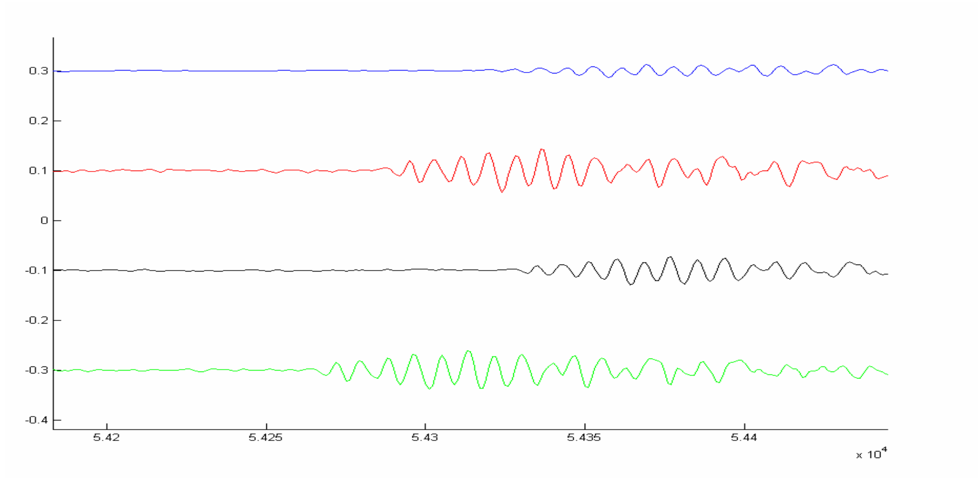

Figure 3: Incoming Signals are Phase Shifted

With the cross correlation performed, and delta t parameters available, the triangulation algorithm described in the Design Specification was used to solve for non linear equations and return the X Y and Z coordinates of the sound origin. This vector was then normalized to return a unit vector pointing in the direction of the shot. Triangulation equations below were solved using Matlab's Optimization Toolbox and the fsolve command. A starting guess of [X Y Z r] = [0 0 0 1000]; (where XYZ are the guessed coordinates, r is the guessed range and all distances are in meters) was used to calculate the location. The reason this initial guess was used was in order to avoid finding erroneous roots located in the area of space between the sensors, but rather look for solutions located in space outside the sensor array boundaries. By forcing the solver to look for distant solutions first, and converge towards 0, we insured that the proper solution was the one found.

The method of triangulation and detecting the phase delay in the 4 signals was consistent with that specified in the design specifications. Phase detection accuracy was limited to 64 samples, that is because at 44100Hz sampling rate, it takes a period of 64 samples for the sound to travel 0.5 meter distance separating the sensors in the array.

3.3 Graphical User Output

The user interface displays all the useful information regarding the location of the origin of the gunshot in a simple format of the azimuth and elevation variables commonly used in the military and enforcement agencies. The information to be displayed is read from a file generated by the detection program. The coordinates in Cartesian format are converted to azimuth and elevation and shown on a display. An example of this is shown below.

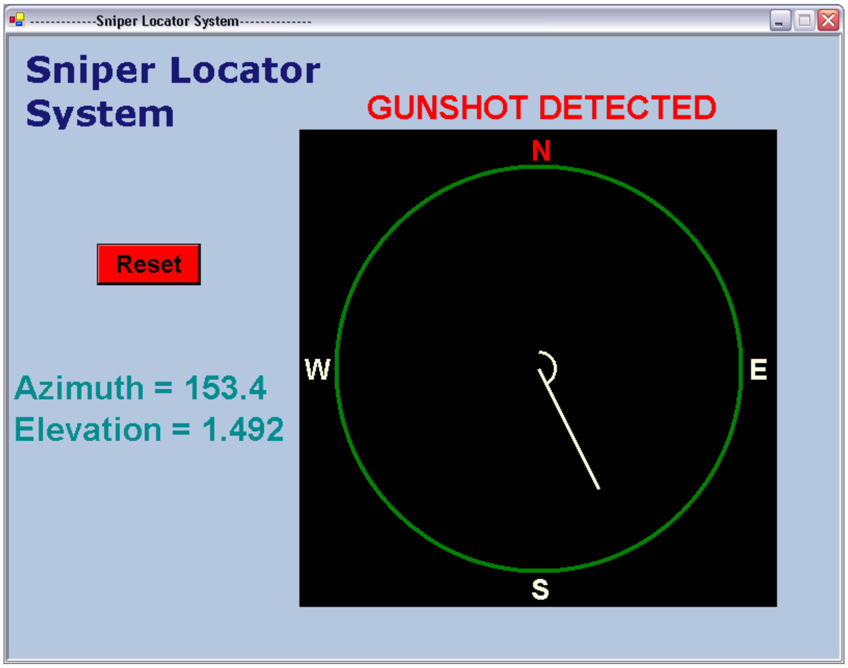

Figure 4: Sample GUI Output

The GUI is an executable file that can be opened on any windows based PC. No additional software needs to be installed to run the application on a computer. Since the GUI is windows based program, no training will be required for the user; although basic computer knowledge will be essential. The GUI data will update every 1-2 seconds and a flag which is encoded into the input text file, will inform the user if the system is operating properly or if there is a problem. If a gunshot is detected, the user must push the reset button on the GUI to reset the system to scan for another gunshot. The location of the last gunshot will not clear if the reset is not pushed. This is to ensure that the user records the information they need before commencing further processing. If a sound that is a not a gunshot is detected, it will inform the user and reset itself to listen for a gunshot. On other key element of the GUI is that the system gives a location with respect to true north, which must be determined prior to program use.

5. Group Dynamics

In all the years of studying engineering science and taking numerous courses we have learned theories and means of applying them to real life applications. During ENSC 440 and ENSC 305, we gained experience on how to manage a project, co-ordinate work between several people, perform our absolute best as a team and to meet deadlines.

No major group dynamic issues were experienced in AcousticShield Design's group. During our weekly meeting, we discussed what had to be done in the following week and assigned tasks to individuals. In certain stages of the project, assigning tasks to members individually was difficult, as the other stages strongly depended on the outcome and performance of another stage. (i.e. the GUI design could have not been started before the completion of the software design's output). This allowed us to work together as a team.

Several excellent advantages were experienced in working together as a team. Working in a team allows frequent updates on the project; furthermore four talents together can achieve a lot more. Working as a team did not constrain us on testing their individual ideas on the project.

However, if we were to undertake a similar project again we would assign task to each person as well as working together when needed. Also we would have different members of group to manage the group for one week and give a progress report on all other members at the end of each week. This also helps to keep all the group members on the same "page".

6. Future Work

Our goal in the initial design was to make a device that accurately locates a gunshot. Now that we have achieved it, for the next prototype our goal would be to optimize both the hardware circuit and the software

6.1 Hardware Optimization

Our current design does not implement a hardware solution to detect the gunshot. Using a high end DSP controller to detect and analyze the gunshots (or non gunshots) would be the ideal way to proceed to the next stage of this system. It would allow for much faster computations for quicker results and the audio codecs would be much more refined for better sampling of the incoming sound signals. One large disadvantage to DSP design would be the high cost of a good DSP controller.

6.2 Software Optimization

To design a system with DSP, a Windows XP compatible board would be ideal so that coding would be easier for programming. We can then move on to optimizing the algorithm and designing the system for multiple types of gunshot detection. If the budget allowed, designing the system for echoes would complete the system to be used in the real world.

6.3 Marketing Plans

No plans for marketing the device have been developed at this time since the design is in its development stages as of yet. As the product becomes ready for real world use, marketing may be considered depending on whether the device can be manufactured at a economic cost.

8. Conclusion

We are proud to announce that AcousticShield Design's has developed the proof of concept of an gunshot detector. By denying the shooter anonymity and enabling quick and accurate localization, our system could enable military and law enforcement personnel to quickly and effectively locate and respond to such attacks. Moreover, we managed to complete the project approximately within the planned budget and managed to meet all deliverable deadlines, along with the final project deadline. The successful completion of the initial design has enabled us to realize the value of this project. Overall, this project has equipped us to become better team members and development engineers for the future.