Detecting the Position and Number of Sharks in the Sea Using Active Sound Navigation and Ranging (SONAR) Technique

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***Abstract*— SONAR which stands for Sound Navigation and Ranging can detect and locate objects under the sea by echoes, much as marine animals navigate using their natural sonar systems. This paper presents the design of a matched filter and the use of Sonar to detect the position and number of sharks in the sea. This was accomplished by the use of a discrete noise signal which generated the used echo. The noise signal was save in a format which can be assessed by a MATLAB programme. A replica of the original sonar signal is made and matched with the original sonar using autocorrelation.**

***Index Terms*— SONAR, noise, signal, autocorrelation detecting**

I. INTRODUCTION

Divers are exposed to danger of attack by large fishes such as shark and detecting their presence and distance will serve a form of protection for the divers. Sonar (Sound Navigation And Ranging) is a technology which employs the propagation of sound signal to detect object and there position. This involves two techniques viz; passive sonar and active sonar. The passive sonar entails listening to the sound produced by an object and active sonar which is the technique used by the diver in this present problem involves emitting pulses of sound and listening for the echoes. Active sonar uses a source of sound combined with an acoustic receiver to ensonify and thereby detect and clasify an object [1]. The diver would like to know if there are sharks, their number and distance from his position. He is equiped with sonar echo transmitter/receiver device from which the sonar "pulse" is transmitted in the direction of the shark and the received "pulses" are buried in additive noise which can be detected using a matched filter. A matched filter is designed to minimize the effect of noise and maximize the signal noise ration (SNR). Through-water telesonar (i.e., telecommunications sound navigation ranging) using digital communications theory and digital signal processor (DSP) electronics is the basis for these underwater networks [2, 3]. Active acoustic detection, using single or multi-beam echo sounders or other sound navigation and ranging (SONAR) systems, has been used as a tool to study fish densities [4] and some swimming and schooling behaviours [5, 6].

This report presents the methods, materials, results, discussion and conclusion in the designing of an appropriate matched filter.

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II. MATERIALS AND METHODS

The materials used for the research are a computer with Matlab loaded and a discrete noise signal which was to generate echo to be used. The discrete noise signal was saved as 'sonar_signal.txt' into the working directory carrying Matlab and was then read into the Matlab using the following Matlab command:

```
fid=fopen('sonar_signal.txt','r');
[A,Flength]=fscanf(fid,'%f',[1,inf]);
```

The Matlab command *fopen('sonar_signal.txt','r')*, opens a file whose name and extension is in the parenthesis and 'r' signifies read permission.

[A,Flength]=fscanf(fid,'%f',[1,inf]) scans the values from the file into A and reuses the format throughout the file so that a control loop is not needed. *%f* specifies the format to be of floating point and *[1,inf]* identifies the discrete values as 1 column and to be read to the end of the file. *'A'* indicates the variable allocation for the discrete noisy signal. The first part of the MATLAB code handles the statistical analysis of the discrete noisy signal. The maximum and minimum values of the noisy signal were calculated as 311.7380 and -312.6216 respectively. The mean and standard deviation values were also calculated as 0.3438 and 146.2418 respectively

III. RESULTS AND DISCUSSION

Fig 1 present the plot of the discrete noisy signal which is a mixture of the original signal buried in noise. It can be seen from the figure that the received signal has got no specific pattern over the entire length of the discrete signal that can be read or translated. This is because it is buried in noise which is an unwanted sound and usually with irregular frequency. The noise has distorted the echo signal which carries information required by the diver to detect the distance, size and number of sharks. The high amplitude of the noise has made the echo signal hardly recognizable. The amplitude of the discrete noisy signal varies between -300 to +300; this is evident in Fig 1.

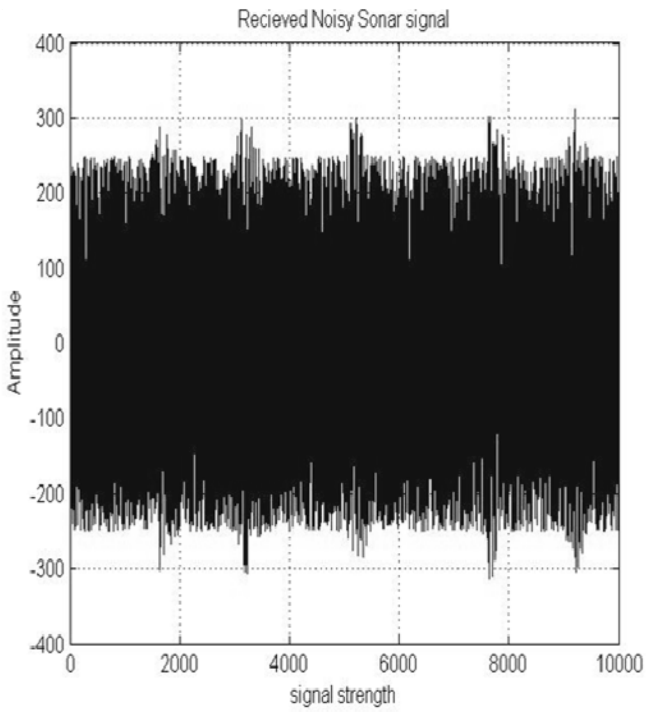

Fig 1: Noisy Sonar Signal

The sources of noise underwater include ambient noise in the sea due to sea-state; shipping noise and wind blowing on the surface is also a significant cause of noise [7].

A. *Histogram*

The histogram presented in Fig. 2 is meant to show a graphical representation of the frequency distribution in relation to amplitude of the Noisy Sonar Signal (NSS). It is clear from the histogram that the amplitude with highest frequency of above 1200 is +150 and with a wide range of amplitude from -200 to +200, the difference in frequency is less than 100. The extreme amplitudes of -300 and +300 are seen to have the lowest frequncies.

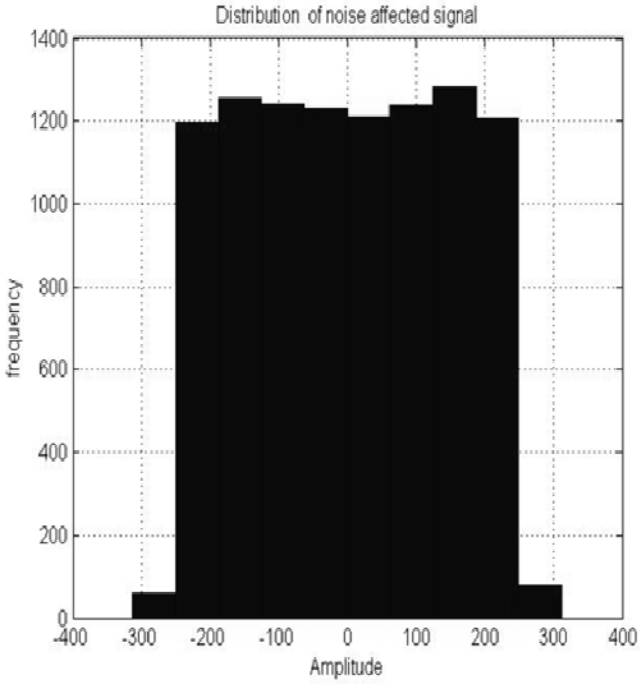

Fig 2 : Histogram of Noisy Sonar Signal

B. *Autocorrelation*

Auto-correlation which is the correlation of a signal with itself describes the general dependence of the values of the samples at one time on the values of the samples at another time. The output of the auto-correlation of the NSS (with no visible rhythm) shows a strong correlation in the middle which implies no shift or lag and because of the use of xcorr in the MATLAB code the number of samples has been doubled.

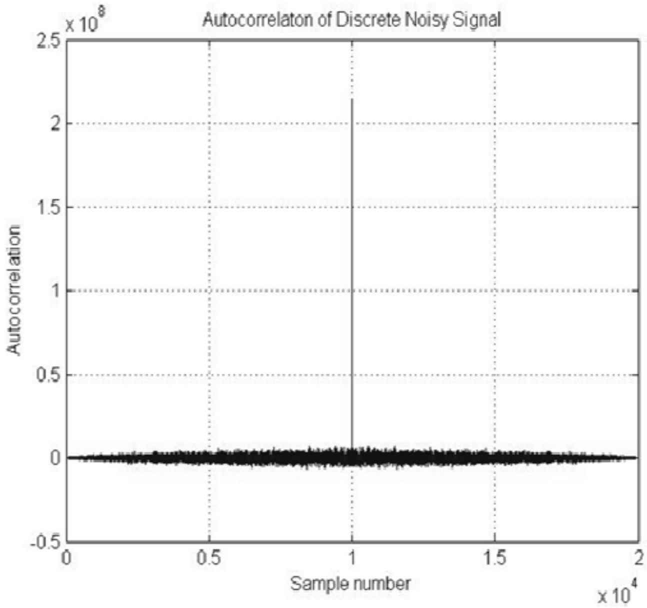

Fig 3: Auto-correlation of the Discrete Noisy Signal

C. *Spectrum*

Fig. 4 displays the noisy signal's spectrum which represents the signal in the frequency domain. To obtain the spectrum in Fig. 4, Fast Fourier Transform (FFT) was applied over a sampling frequency of 10000 Hz using a MATLAB code. The spectrum does not show any distinct frequency value as can be seen in Fig. 4, this is not unconnected with the fact that the original signal is burried in noise and the FFT of a noisy signal in the time domain will obviously give an unclear or a random effect in the frequency domain.

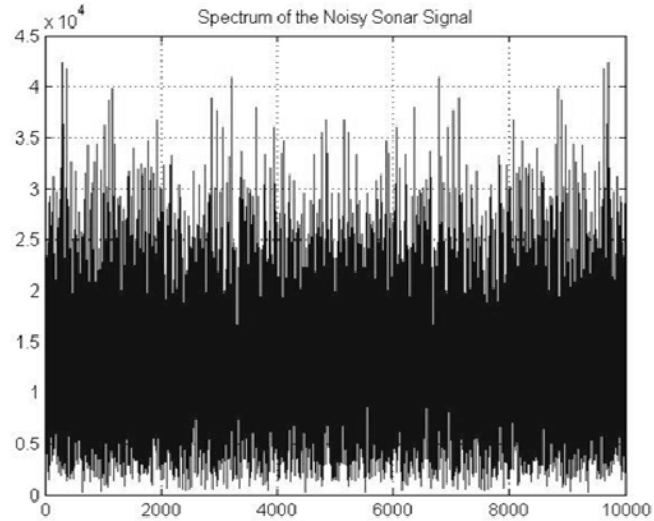

Fig 4: The Spectrum of Noisy Sonar Signal

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D. Replica sonar "pulse" sequence

The knowledge of the form/shape of the original signal is of utmost importance to be able to create a replica which is in-turned matched with the original signal. It is given that the pulse consists of a single sinusoid (s(t) = sin(2πft) that is windowed in the time domain by a triangular envelope. The window length is 512 samples and the period of the sinusoid is 32 samples. Using the given sets of co-ordinates for line a: (0,0.0) - (170,1); line b: (170,1) – (512,0); line c: (0,0.0) – (170,-1) and line d: (170,-1) – (512,0), the lines can be generated by creating equations of a straight lines.

Employing the equation of a straight line

$$y = mx + c \qquad 1$$

Where m is the gradient of the line and expressed as

$$m = \frac{y_2 - y_1}{x_2 - x_1} \qquad 2$$

For line a, 2

$$m = \frac{1.0 - 0.0}{170 - 0.0} = \frac{1}{170}$$

The equation for line a is thus

$$a = \frac{1}{170}x$$

This procedure was adopted to get the equations of other lines b, c and d.

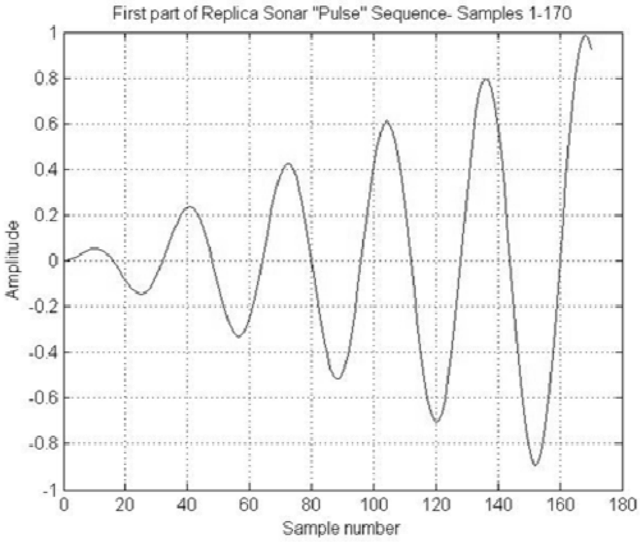

Fig 5: First part of Replica Sonar "Pulse" Sequence – Samples 1-170

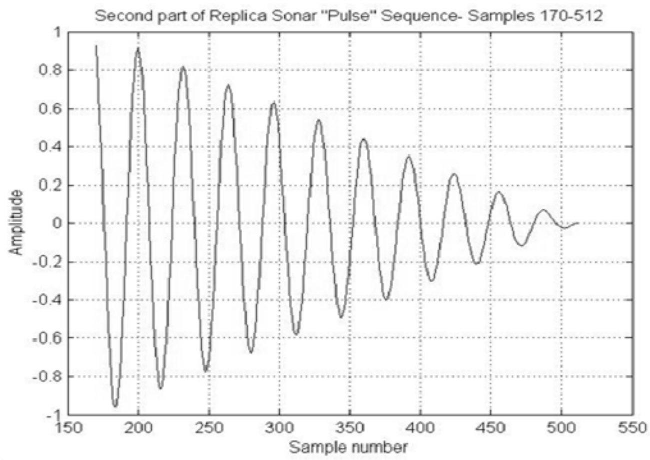

Fig 6: Second part of Replica Sonar "Pulse" Sequence – Samples 170-512

Fig 5 below presents the first part of the replica, spanning from sample number 0 to sample number 170 while fig. 6 shows the second part of the replica spanning from sample number 170 to sample number 512. Fig. 7 presents the complete replica sonar signal (combination of the first and second part) which shows the effect of windowing a regular sinusoid with straight lines whose co-ordinates were given over a sample length of 512.

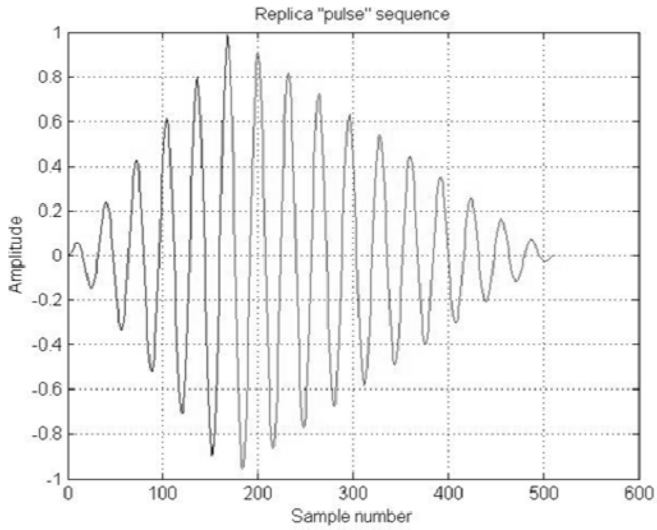

Fig 7: Second part of Replica Sonar "Pulse" Sequence – Samples 170-512

E. FIR Filter Weights

An FIR filter is a "moving average" filter. Fig 8 presents the Finite Impulse Response filter weight which was obtained using MATLAB code to flip over or reverse the replica sonar pulse sequence.

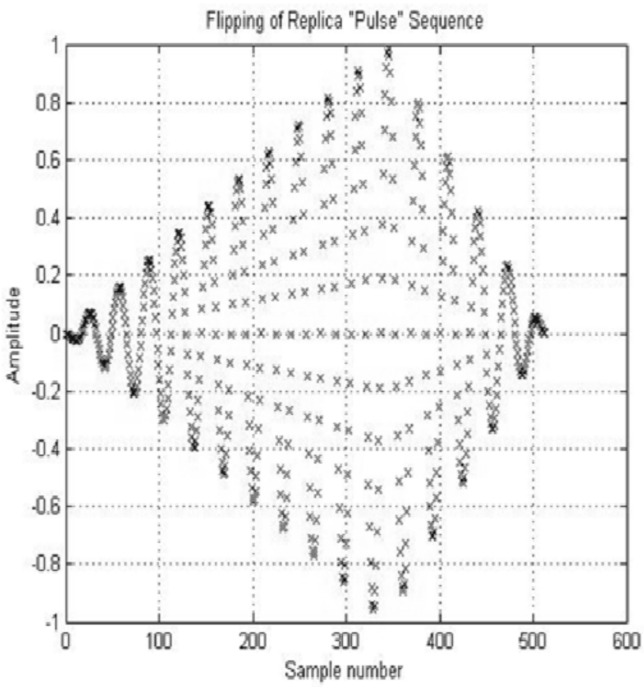

Fig 8: 'x' points representing discrete filter weights

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F. Detecting the Sonar 'pulses

It is well known that the matched filter is the optimum receiver for the processing of a known signal in a background of additive noise [8]. After calculating the replica sonar signal, the noisy sonar data is matched with the impulse response generated using replica sonar signal by applying the theory of convolution. This was done in MATLAB code; the two signals were convolved to obtain a matched filtered signal in Fig. 9

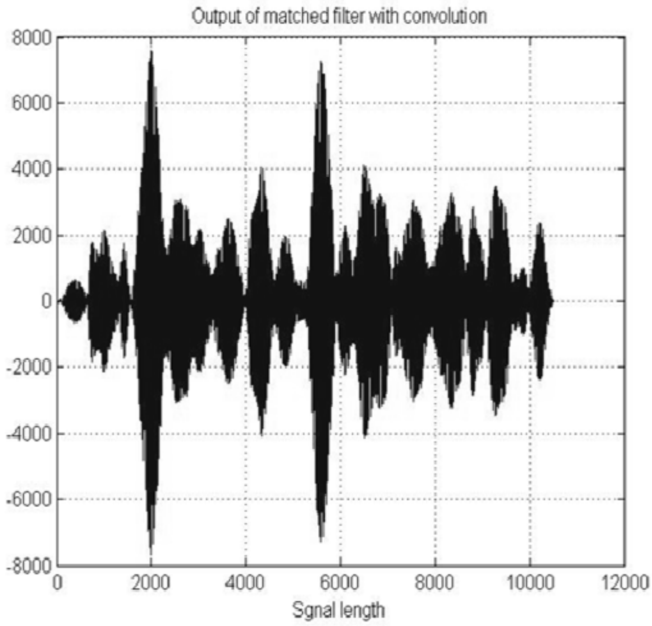

Fig 9: Output of Matched filter after convolution

Fig. 9 shows that the convolution of the two signals has drastically reduced the presence of noise and it is showing a visible pattern when compared with the original signal Fig. 1. Although Fig 9 is not the ultimate, it is a far cry from the original signal. Fig. 9 can be made better and easy to interpret when threshold is used. The output of the convolution was subjected to a threshold level of 0.6*max(output). Fig. 10 shows the thresholded output from indicating zero at all sample numbers except at 1982 and 5578 were it is non-zero.

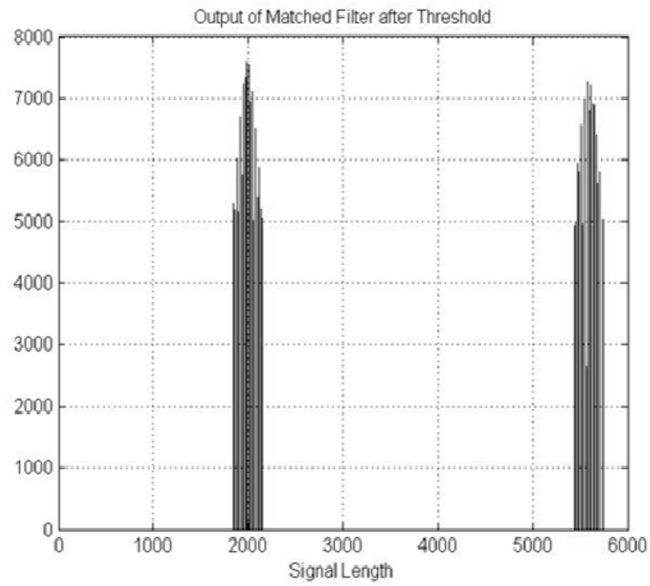

Fig 10: Output of Matched filter with threshold applied

G. Estimating the Distance of each Shark

With the knowledge of the sample number at which a non-zero occurs and the sampling period (0.05ms), the time at which the sample number of 1982 and 5578 occurs can be estimated as follows:

Let t_1 be the time at which sample number 1982 (corresponding to the position of shark 1 (S_1)) occurs and t_2 be the time at which sample number 5578(corresponding to the position of shark 2 (S_2)) occurs;

Therefore

$t_1 = 0.05 \times 10^{-3} \times 1982 = 0.0991s$and

$t_2 = 0.05 \times 10^{-3} \times 5578 = 0.2789s$

The distance of the sharks can be estimated from the elementary relationship of velocity, distance and time as follows knowing that the velocity of sound in water is 1497ms^{-1}:

$$D = velocity \times time \qquad 1.3$$

The time in equation 1.3 is the time taken for the signal to travel to the shark and return in form of echo. This implies that the distance is half equation 1.3

Therefore

$$D_1 = \frac{v \times t_1}{2} = \frac{1497 \times 0.0991}{2} = 148.35\ m$$

$$D_1 = \frac{v \times t_2}{2} = \frac{1497 \times 0.2789}{2} = 412.49\ m$$

The distance of shark 1 is 148.35 m and of shark 2 is 412.49 m from the diver. The size of the shark correspond to the width of the pulse as shown in Fig. 10 which is an indication of the amount of the original signal that is reflected by the shark as echo. From Fig 10 the sizes of shark 1 and shark 2 are almost the same because the width of the pulses are about the same.

IV. CONCLUSION

Sonar- a method of detecting, locating and determining the velocity/distance of objects using a transmitted and reflected underwater sound wave is an important technology in signal processing. The reflected signal is usually buried in noise thereby making the signal unclear with no visible pattern. A matched filter was designed through autocorrelation to convolution and thresh holding the output of convolution to make the given noisy signal have a visible pattern. These visible pulses were interpreted to get the number of sharks to be two, the distance of the sharks to be 148.35 m and 412.49 m respectively.

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