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SIGNAL PROCESSING IN SEA MINES

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ABSTRACT

Various influences generated by target ships and submarines are mentioned in the introduction of this paper. In this paper the major criteria in the development of naval mines are listed. Different Sensors used for sensing various influences are covered in this paper. The targets influences gets embedded into the Sea ambient. Extraction of desired target influences eliminating Sea ambient is a tedious process. Hence advanced digital signal processing and digital filtering techniques used in the mines design for target detection, classification and detonation are highlighted in this paper.

Keywords: Ambient, DFT, FFT, LMS, Sensors.

I. INTRODUCTION

The mine in underwater warfare is most potent, cost effective and lethal weapon. Mines can be used both strategically and tactically to deny waters from hostile forces and to defend high value targets such as ports, anchorages and offshore structures from amphibious and sea born attack. Modern influence mine fuses are usually equipped with several measurement channels, including acoustic (detecting the sound of the target ships and submarines), magnetic (detecting the metal in a ship and submarine), and hydrodynamic (Pressure) (detecting the pressure on the water a ship and submarine over head makes). Various advanced signal-processing algorithms to improve the probability of detection in difficult environmental conditions or during high tides are required to be adopted. Hydrodynamic fields generated by ships can be heavily distorted by waves or underwater currents, complicating the process of ship detection. [1] Current naval mines are "smart mines", containing its own computer (Processing system), and able to detect targets via acoustic ,pressure, and magnetic sensors. The computer in these mines are programmable, so the mine can be instructed to attack only certain types of ships. If the mine sensors do not detect the right combination of characteristics, they do not detonate. [2] Various signal processing techniques required to be incorporated in the present sea mines design are discussed in this paper.[3]

II. THE MAJOR CRITERIA IN THE DEVELOPMENT OF NAVAL MINES ARE LISTED HERE: [4]

2.1. Ggreater detection range of targets with low levels of physical fields.

2.2. .Eengagement of fast-moving targets, including submarines and dynamically- supported ships.

2.3. Modernization of existing exploders and development of new unified versatile multipurpose exploders.

2.4. Reduction of visibility of bottom and moored mines; enhancement of the selective capability and anti-sweep resistance of mines; remote control of the "armed – unarmed – sterilizer" status of mines.

2.5. Improvement of onboard power supplies.

2.6. Development of multipurpose transportable mines.

2.7. Rreduction of target attack time and simultaneous enhancement of reliability and noise immunity of mines; optimization of target selection from a group of targets. optimization of the attack trajectory.

2.8. Improvement of weight and size characteristics.

2.9. Development of systems adapted in terms of their dimensions to aircraft and submarines of all navies in the world.

IV. VARIOUS SENSORS USED IN THE SEA MINE DESIGN: [5] [6]

4.1 One acoustic sensor for detecting the sound of the target ships and submarines.

4.2 There are three identical magnetic channels on X,Y,Z axis. Hence three single access magnetometers are used to detect the magnetic influence generated on each access by target ships and submarines.

4.2 One pressure sensor is used for detecting the pressure on the water a ship and submarine over head makes.

4.4 One depth sensor is used to measure the depth at which the mine is lying in underwater.

V. VARIOUS SIGNAL PROCESSING ALGORITHMS USED IN THE SEA MINES DESIGN: [7] [8]

In order to detect, classify, localize, detonate and destroy target ships and submarines efficiently by Sea mines, various methods used and different advanced signal processing techniques implemented in the mines design are briefly mentioned here.

5.1 A method for background normalization.

5.2 A method for adaptive thresholding to reduce noise.

5.3 A method for extraction 0f target influences.

5.4 A method for validating the target influences.

5.5 A method for target correctness.

5.6 Implementation of Fast Fourier Transform (FFT) algorithm for conversion of tome domain signal into frequency domain signal.

5.7 Implementation of Least Mean Square (LMS) algorithm for desired signal extraction.

VI. SIGNAL PROCESSING

The various channels data in digital form is processed by its own computer (Processing system) built into the mine design for:

- Study of sea ambient conditions
- Disabling of channels expected to be saturated
- Channels thresholds fixing

- Target detection
- Target identification
- Target conformation
- Target localization
- Mine detonation

VII. SPECIAL FEATURES

The special features generally incorporated in the present day Mines design are advanced digital signal processing and digital filtering techniques. They are Fast Fourier Transform (FFT) processor and Least Mean Square (LMS) filter. They are briefly described here.

7.1 Fast Fourier Transform (FFT) Processor: [9] [10] [12] [13]

Fourier Transform has long been a principal analytical tool for signal processing applications in speech, telephony. Radar Sonar etc., and the FFT has evolved as an efficient algorithm for computing the Discrete Fourier Transform (DFT) Different architectures such as sequential pipeline, parallel and array processor for realizing FFT processors are available. A sequential processor can be characterized as having one arithmetic unit and $\frac{N}{2}$ ($\log_2$ N) butterfly operations performed sequentially to compute a N-point transform On the other hand, pipeline organization utilizes $\log_2$ N arithmetic units, each of which performs $\frac{N}{2}$ butterfly operations sequentially The parallel processor uses $\frac{N}{2}$ arithmetic units to transform $\log_2$ N butterfly operations while an array processor employs $\frac{N}{2}$ ($\log_2$ N) arithmetic units each performing one butterfly operation.

Basically there are two forms of the FFT algorithm, namely, the Cooley - Tukey and the Sande-Tukey formulations. The Cooley - Tukey algorithm is often referred to in the literature by the term Decimation-in-time Analogous to this, the Sande - Tukey algorithm is termed as Decimation-in Frequency.

In Mines, the sequential FFT processor can be implemented through software through various phases. In the first phase, the data is to be written into the memory in a scrambled (bit reversed) order for using Cooley - Tukey algorithm. Bit reversing is achieved by taking the mirror image of the binary representation of the address. In sequential FFT processing, an N-point transform is computed by performing $\frac{N}{2}$ $\log_2$ N butterfly operations sequentially, Basic butterfly operation for a radix-2 Decimation-in-Time algorithm is shown in fig 1.

The butterfly operation is defined by

$$\mathbf{x_m(k) = x_{m-1}(k)+w^p x_{m-1}\left(k+\frac{N}{2^m}\right)}$$

$$\mathbf{x_m(k+N/2^m) = x_{m-1}(k) - w^p x_{m-1}\left(k+\frac{N}{2^m}\right)}$$

$$\textbf{where } \mathbf{w= exp -\left(\frac{j2\Pi}{N}\right)}$$

In general the input and output nodes of the butterfly are complex nodes. Therefore, if we assume

$x_m(k) = x_{1R} + jY_{1l}$

$x_m(k+\frac{N}{2^m}) = x_{2R} + jY_{2l}$

$x_{m-1}(k) = S_{1R} +- jS_{1l}$

$x_{m-1}(k+\frac{N}{2^m}) = S_{2R} + jS_{2l}$

and $w^p = e^{-j\left(\frac{2\Pi}{N}\right)^{nk}} = e^{-j\Theta} = \cos\Theta - j\sin\Theta$

then $X_{1R} = S_{1R} + S_{2R}\cos\Theta + S_{2l}\sin\Theta$

$Y_{1l} = S_{1l} - S_{2R}\sin\Theta + S_{2l}\cos\Theta$

$Y_{2R} = S_{1R} - S_{2R}\cos\Theta - S_{2l}\Theta\sin\Theta$

$Y_{2l} = S_{1l} + S_{2R}\sin\Theta - S_{2l}\cos\Theta$

The magnitude function of the Fourier spectrum can be computed from the real and imaginary parts.

$X(w) = \sqrt{X^2{}_{re} + X^2{}_{im}}$

To facilitate faster computation, the spectrum may be approximated by

$X(w) = L + \frac{3}{8}S$

Where, L is the largest and S the smallest of X_{re} and X_{im}

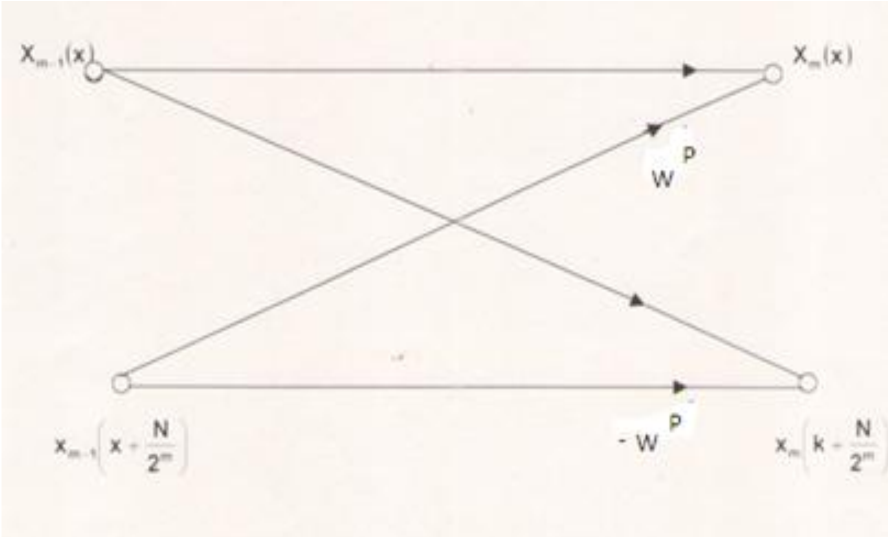

Fig1. Dual node (Butterfly) computations

7.2 Least Mean Square (LMS) Filter: [10] [13]

In the Mines, a self-optimizing filter known as LMS filter is used. Filters are normally used to eliminate unwanted signals from incoming signals. Here the LMS adaptation algorithm of windrow and Huff is used to self optimize to the highly random signals and detect the deviation caused to these signals due to external disturbance. The equations used in LMS implementation are listed here. The iterative process continue until the weights converge. [11] Use the converged weights to extract desired signal by eliminating undesired ambient.

$$y(n) = w^T(n-1)\,u(n)$$

$$e(n) = d(n) - y(n)$$

$$w(n) = \alpha w(n-1) + f(u(n), e(n), \mu)$$

The variables are as follows:

Variable	**Description**
N	The current time index
u(*n*)	The vector of buffered input samples at step *n*
w(*n*)	The vector of filter weight estimates at step *n*
y(n)	The filtered output at step *n*
e(n)	The estimation error at step *n*
d(n)	The desired response at step *n*
μ	The adaptation step size
A	The leakage factor ($0 < \alpha \le 1$)

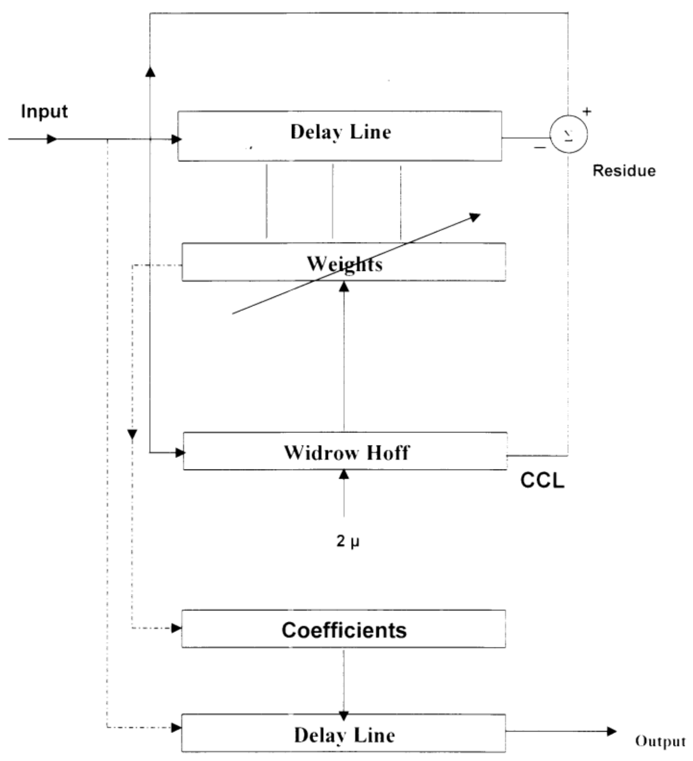

Fig.2: Application of LMS in mines design.

VIII. CONCLUSION

The types of influences generated by various targets namely Ships and Submarines are identified. Accordingly suitable sensors used to achieve success in target's data acquisition, processing, targets localization and destruction are widely discussed. Advanced signal processing techniques required to be used to achieve desired results are explained at great length.

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