A COMBINATED LMS-WNC ALGORITHM IN LOCALIZATION OF UNDERWATER TARGET

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ABSTRACT

The WNC algorithm is an adaptive MFP which is developed in order to improve the capability of locating underwater objects and counter the fluctuation of various unmatched envinronment. However, the effectivity of WNC algorithm in high noise, interference envinronments has some drawbacks. This paper presents the result of the combination LMS and WNC for the purpose of reducing the interference's effect on locating objects and enhancing the quality of object resolution. The simulation results show that LMS-WNC improved the probability of detecting, locating the object having the signal with low SNR comparing to WNC algorithm.

KEYWORDS: *Hydrophone localization, least mean square- LMS, matched field processing – MFP, shallow water, white noise constraints - WNC.*

I. INTRODUCTION

MFP algorithm is widely used to localize underwater target in shallow water [1-5]. In order to enhance capability of localization, several adaptive MFP algorithms are developed. For example, WNC is one of these has several advantages such as improving the quality, located object resolution, countering the unmatched environment in some cases [6]. Nevertheless, the effectiveness of the algorithm in severe interference environment is a huge challenge. Therefore, the solution is that WNC can be used with adaptive filters in pre-processing for filtering interferences prior to load to WNC. There are many research using adaptive filters to reject interferences. In particular, LMS is popular to eliminate audio interferences in many applications [9,10,11]. This paper proposed the combination of LMS and WNC to reduce the impact of interference with low SNR and to increase the localization capability of target. The research has 5 sections: the first part is to study on MFP, WNC, and LMS. The second part is about recommendation of LMS-WNC algorithm. The third one is an observation of environment model, the fourth one is simulation, evaluation and comparing the quality of localization based on WNC, LMS-MFP, LMS-WNC, and then the conclusion.

II. MFP, WNC ALGORITHMS

2.1. MFP, WNC Algorithms

The output energy of MFP processor is caculated [7]:

$$B = \mathrm{w}^H \mathrm{R}\mathrm{w} \qquad (1)$$

Where R sample-average cross-spectral density matrix (CSVM), calculating based on receiving spectral input at Hydrophones.

In general, weighting vector w is calculated through Acoustic propagation mode:

$$w \cong \nu = \frac{G(r,z)}{|G(r,z)|} \qquad (2)$$

Green function is calculated by [8]:

$$G(r,z) = \frac{i}{\rho(z_s)\sqrt{8\pi r}} e^{-j\frac{\pi}{4}} \sum_{m=1}^{\infty} \Psi_m(z_s)\Psi_m(z) \frac{e^{jk_m r}}{\sqrt{k_m}} \qquad (3)$$

Where r is distance (m), z: depth (m), ρ density, z_s the depth of source (m), Ψm Mode Amplitude, k_m eigenvalue.

In order to enhance the quality, the adaptive MFP is created. In MFP algorithm, weighting vector is determined through signal replica vector ν. In contrast, in WNC weighting vector w is determined by H matrix and diagonal load factors ε, signal replica vector ν, the sample-average cross-spectral density matrix R, as [8]:

$$w_{wnc} = \frac{(R+\varepsilon I)^{-1}\nu}{\nu^H (R+\varepsilon I)^{-1}\nu} \qquad (4)$$

Where I is an Identity matrix

The output power is:

$$B_{wnc} = w_{wnc}{}^H R w_{wnc} \qquad (5)$$

The maximum output energy gives an estimated source position.

2.2. LMS Algorithm

LMS algorithm is a linear adaptive filter algorithm that applied the least mean square to evaluate the filter errors. The updated weighting vector is calculated [9]:

$$w(n+1) = w(n) + 2\mu e(n)x(n) \qquad (6)$$

Where x(n) input vector, w(n) weighting vector of FIR filter at the time n, and μ is to control the size of the steps the weights make, and affects the speed of convergence of the algorithm. Selecting an optimal μ will determine the filter's quality. If μ is too small, it will affect to time of processing. If μ is too high, it will cause an unstable system.

One of the basic applications of LMS adaptive filter is to reject interference [9,10,11]. A particular diagram of adaptive filter is shown [9]:

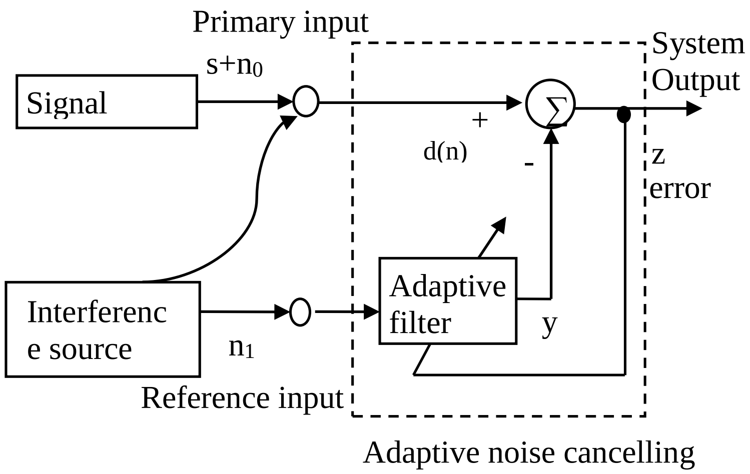

Figure 1. Interference cancellation using adaptive LMS filter

The method of rejecting interference bases on the receiving two channels, in which main channel receiving signal and inference, the second channel is only to receive interference. 2 channel signals and interference lead to filters, the process of filtering interference is based on updating suitable FIR filter factor in equation (6) and selecting appropriate step μ. At a result, the interference will be eliminated and the desired signal is at the output.

III.LMS -WNC ALGORITHM

LMS-WNC Algorithm increases the capability of detecting very small level of signal with low SNR and improves the resolution of surface functions (increase ratio peak background rate - PBR). The scheme of LMS-WNC is shown on the figure 2.

The scheme has 2 process:
- Filtering process: This process includes calculating output of serial filters based on signals lead to band of filters, evaluating the differences between output and desired signal, updates the parameters of the filter.

- Localization process: This process compares acoustic propagation mode, signal replica vector v with filtered signals output of LMS filters, the ultimate correlation between signal replica vector v and filtered signal will give the position of source.

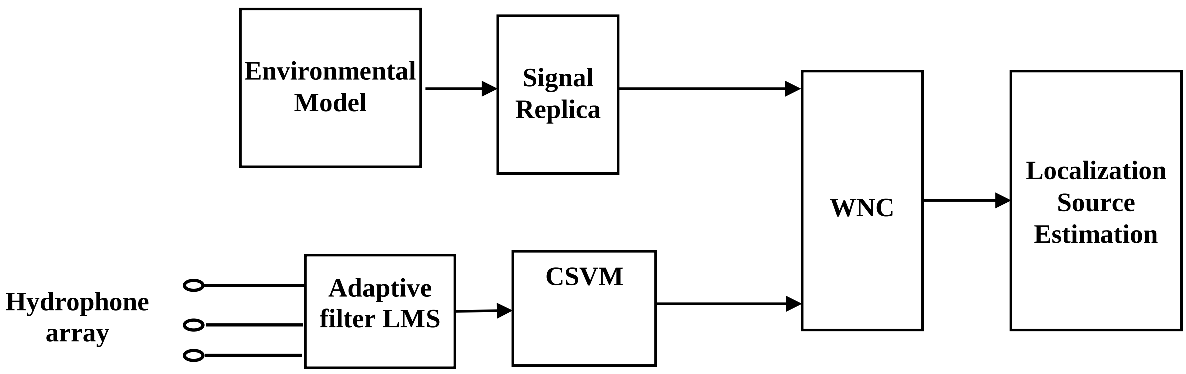

Figure 2. LMS-WNC algorithm

IV. ENVIRONMENT MODEL

In order to evaluate the impact of environment, this research has selected a typical shallow water in Socialist Republic of Vietnam having environmental parameters:
The structure has a water layer, sand layer and bottom layer with fundamental parameters
- Layer water: Sound speed changes about 1522÷1543 m/s, the density ρ = 1.024g/cm^3, the depth 112m.
- Sand layer: Sound speed varies 1520÷1590 m/s, density ρ = 1.75g/cm^3, absorption factor α = 0.5 dB/λ, the depth 12m.
- Bottom layer: sound speed c=1650 m/s, density ρ=1.9g/cm^3, absorption factor α = 0.5 dB/λ.

Table 1. The Parameters of Environmental Model

Layer	Sound Speed	Density	Absorption	Depth
Water	1522/1543	1.024		112
Sand	1520/1590	1.75	0.2	12
Bottom	1650	1.9	0.5	

Above pamameters, sound speed of water layer is the most significant because it depends on other factors such as temperature, salinity, the depth. The density factor represents the reflecting capability of acoustic sound, the obsorption factor represents the capability of obsorbing acoustic sound.

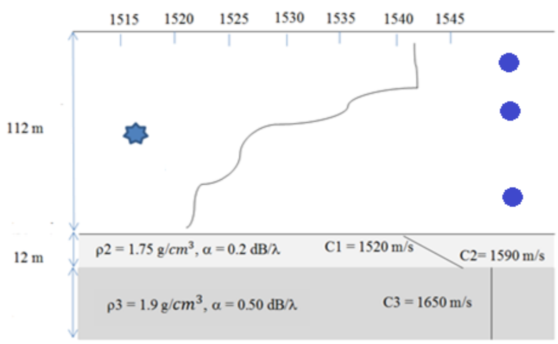

Figure 3. Ocean channel model

V. Simulation Results

5.1. Input data

The Environment parameters in section 4.
Acoustic sound source: linear frequency modulation (LMF) signal with bandwidth 100 to 120 Hz, in a position (distance 2000 m, depth 59 m).
Hydrophone array has 50 elements, set at positions with the depth ranges from 6 to 104 m, separated by 2 m.
Observation zone is divided by a grid with distance from 1 to 3 km, separated by 10 m; the depth from 10 m to 110 m, separated by 2 m.
Simulation using the signal with SNR= -10 dB.

5.2. Simulation result

- The emitted source.

The acoustic source is a linear modulation frequency using acoustic waves with bandwidth 100-120HZ, in postion (distance 2000 m, depth 59 m)

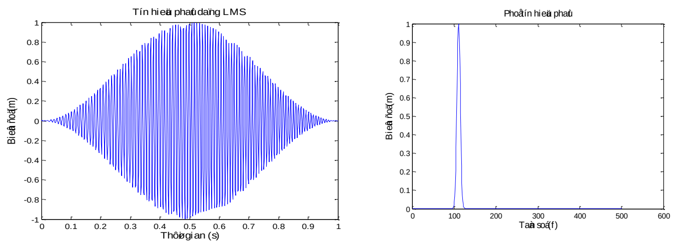

Figure 4. LMS source signal

- Received signals at hydrophones

  The simulation results in Fig.5 demonstrate the at the hydrophone without presence of noise and interference. In contrast, the simulation results in Fig. 6 present the received singals at the hydrophone arrays with the presence of the noise, interference level equal -10 dB. The received signals that is suffered from -10 dB noise is filtered by the LMS filter, and the output signals of the LMS is showed in Fig.7.

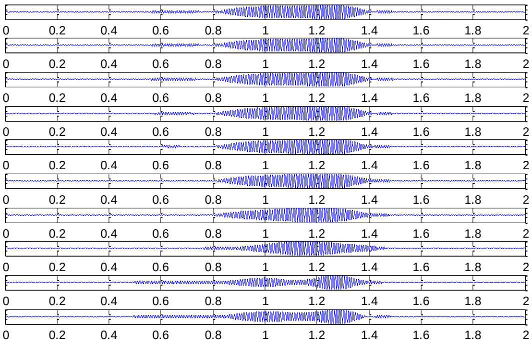

Figure 5. The recieved signals 1 to 10 hydrophones with the absence of interference

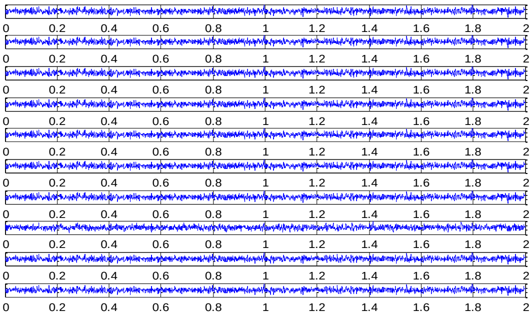

Figure 6. The received signals at 1 to 10 hydrophones when SNR = -10dB

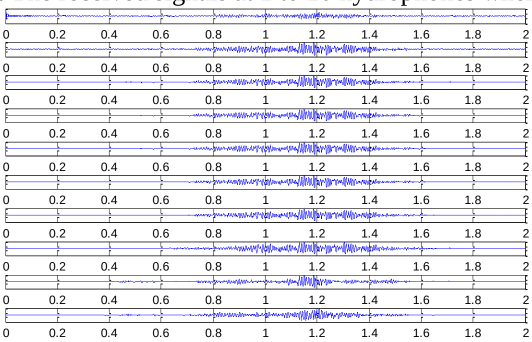

Figure 7. LMS filtered signals in 1÷10 hydrophones when SNR= -10 dB

The simulation results present the ambiguity surface of the WNC algorithm at different noise level such as 0 dB, -5 dB, -7 dB, and which is demonstrated in Figure 8, Figure 9, Figure 10.

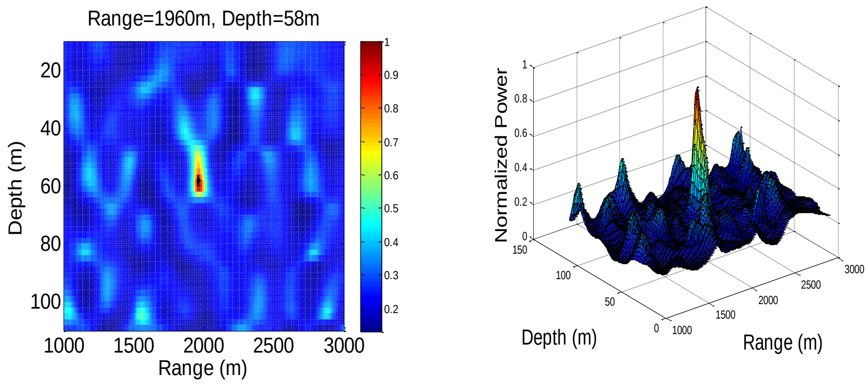

Figure 8. Ambiguity Surface of WNC Algorithm with Noise, SNR=0 dB

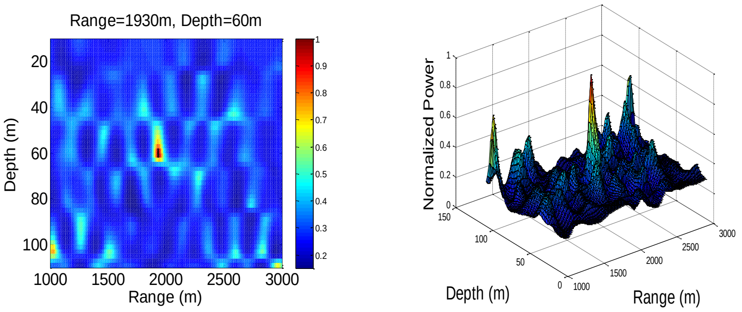

Figure 9. Ambiguity Surface of WNC Algorithm with Noise, SNR=-5 dB

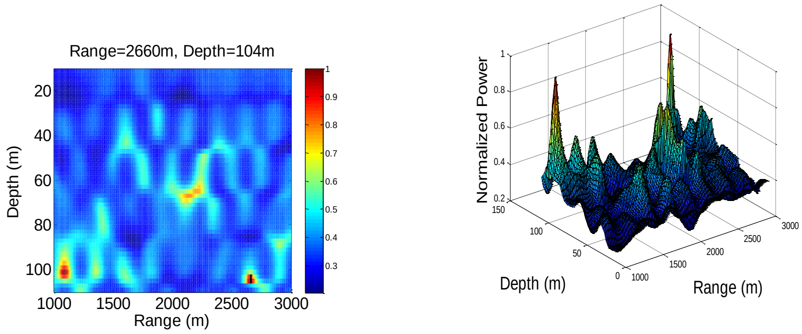

Figure 10. Ambiguity Surface of WNC Algorithm with Noise, SNR=-7dB

The simulations results show that by applying WNC algorithm, the source target could be localized under the interference effects that is at -5 dB. When the interference level is higher than the designed signal 5 dB, the localization results has not been accurate. The lower the SNR of the signal is, the smaller of the PBR of the ambiguity surface is. There are more results of the combinate LMS-WNC algorithm in different interference conditions:

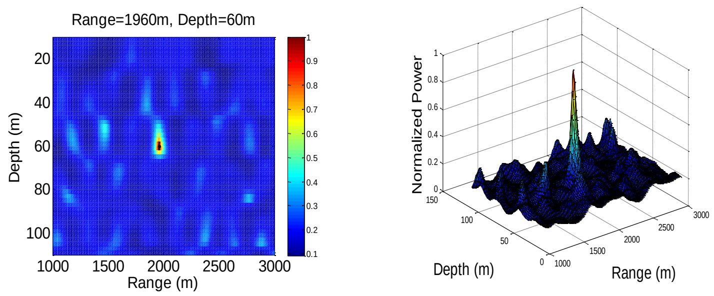

Figure 11. Ambiguity Surface of WNC- LMS Algorithm with Noise, SNR= -7dB

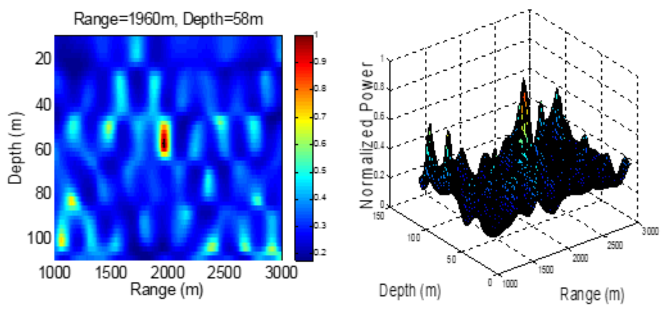

Figure 12. Ambiguity Surface of WNC- LMS Algorithm with Noise, SNR= -15dB

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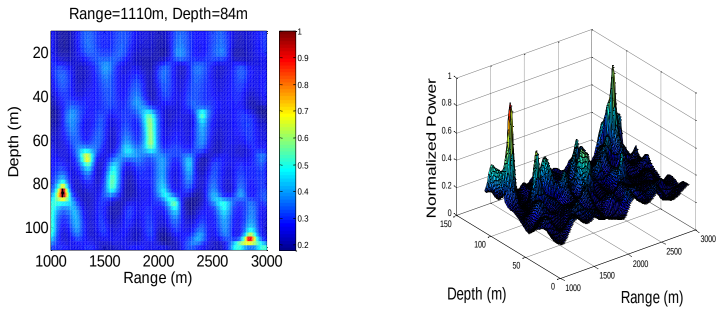

Figure 13. Ambiguity Surface of WNC- LMS Algorithm with Noise, SNR= -20dB

The simulations show that, with only WNC algorithm, the system could be localized the signal that has SNR<= -5 dB. When using LMS-WNC algorithm, the system could be localized the signal that has SNR<= -15 dB. Therefore, the LMS-WNC algorithm could develop the ability to detect the low-level signal as compare with the WNC.

VI.CONCLUSION

The research has studied LMS, MFP, WNC and combinated LMS-WNC algorithms. It also simulated and evaluated the effectivenes of LMS-WNC via comparing the results of using WNC algorithm.
The result proved that if combining the advantages of both LMS and WNC, there are more chances to locate the acoustic sound source. Using LMS -WNC algorithm can highly detect the signal with SNR >= -10dB, while using solo WNC algorithm, the -5dB SNR of the signal could ensure the localization performance.

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