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Enhancement and Identification of The Ultrasonic Echoes

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ABSTRACT :

Adaptive filtering technique has been applied for enhancing and detecting ultrasonic echo signals that are corrupted with noise signals and un-desirable signals. This paper is concerned with enhancing the reflected ultrasonic echoes that are combined with the environmental noise. The adaptive filter is augmented to match the transmission path of the ultrasonic signals and generates a good estimate of the cleaned reflected signal based on minimizing a mean square error criterion. The weight coefficients are updated using the well known LMS adaptation algorithm. The proposed scheme is evaluated by computer simulations.

KEY WORDS :

Adaptive filtering, Ultrasonic signals, Enviromental noise.

I. INTRODUCTION :

Ultrasonography is becoming a valuable diagnostic tool in the study of biological tissues. The energy form employed is high frequency sound waves. They can be directed as a beam, in contrast to the diverse spreading that is inherent with lower frequency sound waves. These mechanical vibrations are nonionizing and noninvasive. The frequencies used in medical diagnosis range between 1 and 15MHz. Since ultrasonography is free of any known adverse effects, it can be used continuously or repeatedly without complications that exist with roentgenographic examination [1].

We have two problems in ultrasonic image: -

a) Image degradation: -

It is caused by inhomogeneous propagation in tissue.

b) Speckle noise: -

The image will have a magnitude that varies randomly with position due to constructive and destructive interference. This leads to the characteristic speckled effect in ultrasonic images.

In this paper a proposal of an ultrasonic enhancer is presented. The proposed scheme is based on the adaptive filtering technique. The purpose of the adaptive filter [2] is to estimate a good replica of the reflected signals from the tissues.
The output of the adaptive filter is subtracted from the received noisy echoes and the filter coefficients are updated such that the mean square of the resulting error signal is minimized [3].
The weight coefficients are updated using the least mean square (LMS) adaptation algorithm. It is found that the proposed scheme provides a large improvement factor in the output signal to noise ratio.

This paper is organized to include six sections. The characteristics of the ultrasonic signal are described in section II and a proposal of an ultrasonic enhancer is presented in section III. The adaptation algorithm is given in section IV, and the simulation results are demonstrated in section V, Finally, Conclusions are given in section VI.

II. THE CHARACTERISTICS OF THE ULTRASONIC SIGNAL :

Ultrasound wave has a frequency range higher than 20 kHz. The longitudinal waves are widely used in medical applications whose frequency range is depicted in table (1). As an acoustic wave propagates through a biological tissue, the energy of the incident wave is portioned into three parts. The first part is absorbed through the biological tissues and is converted into heat.

The second part is reflected from the surface with certain reflection index Ψ_l while the third part penetrates through the tissue with refraction index β_l .Fig. (1) explains the behavior of ultrasonic wave propagation when it is incident on a biologic tissue. An A mode display is simply a graphical depiction of echo amplitude versus distance into the tissue; distance is related to the ultrasonic speed and the time of flight. Figure (2) presents the system components. Ultrasonic images are generated from specular reflection echoes as well as the diffused scattering ones. Therefore, changes in the elastic properties of the tissue may be detectable in acoustic image [4].

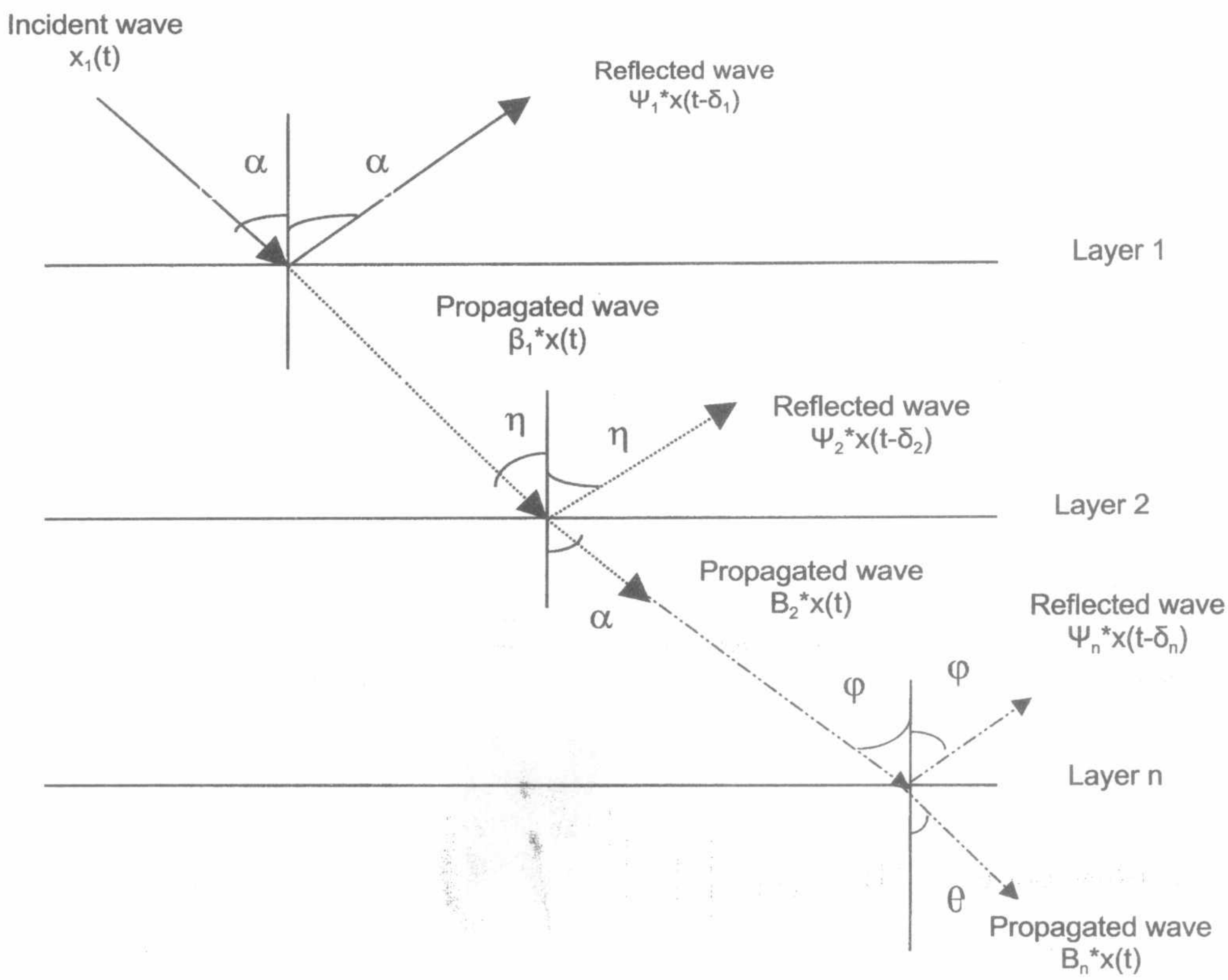

Fig (1) Refraction and reflection of acoustic waves

Organ	Frequency Range
Liver and other abdominal organs	3-5 MHz
Breast and thyroid	4-10 MHz
Eye	7-15 MHz

Table (1)

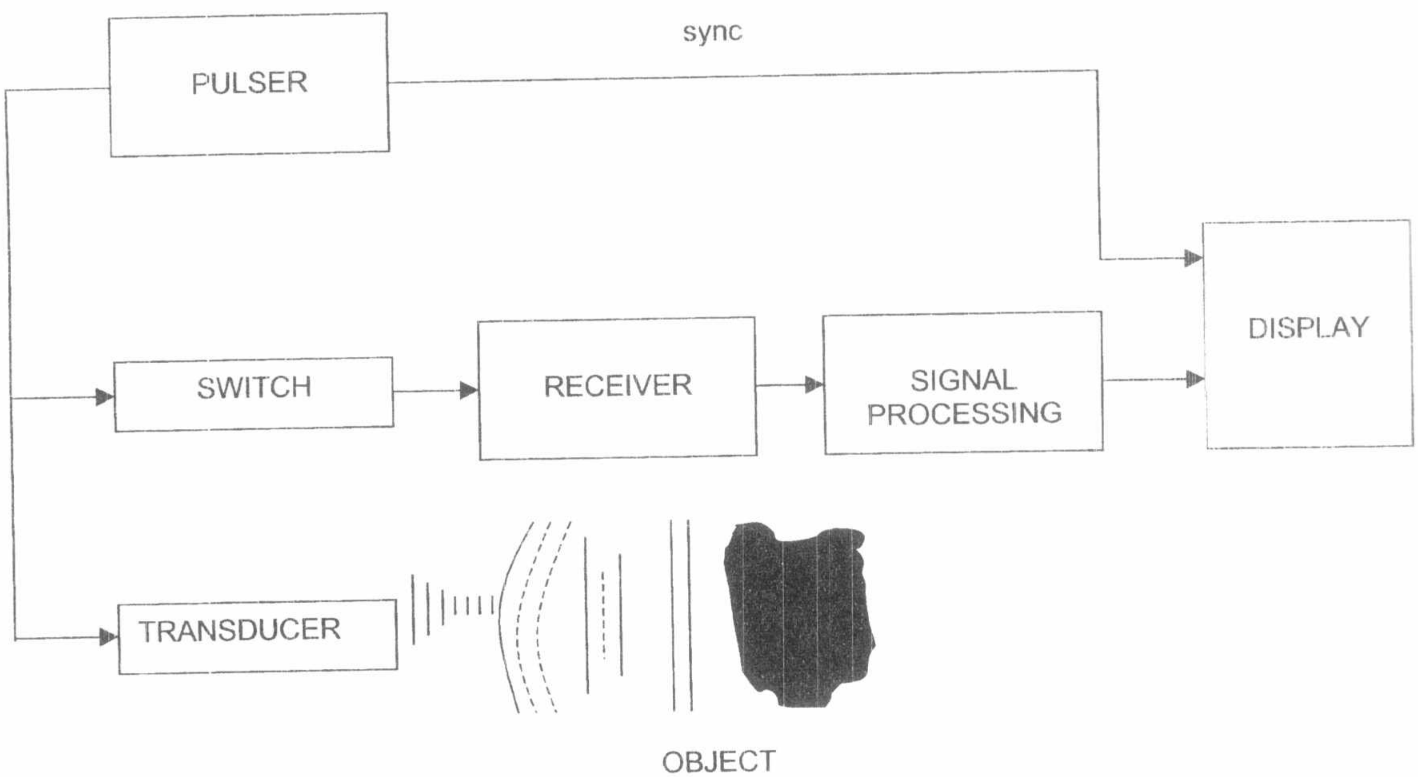

Fig. (2) Block diagram of an A-mode ultrasonic system.

III. THE PROPOSED SCHEME OF THE ULTRASONIC ENHANCER: -

The principle of proposed ultrasonic enhancer depicted in Fig. (3) is to enhance the echo signal which is buried in an environmental noise.
The role of adaptive filter is to obtain a good estimate of desired signal based on minimization of the mean square of the deviation error between the noisy observation and the filter output.

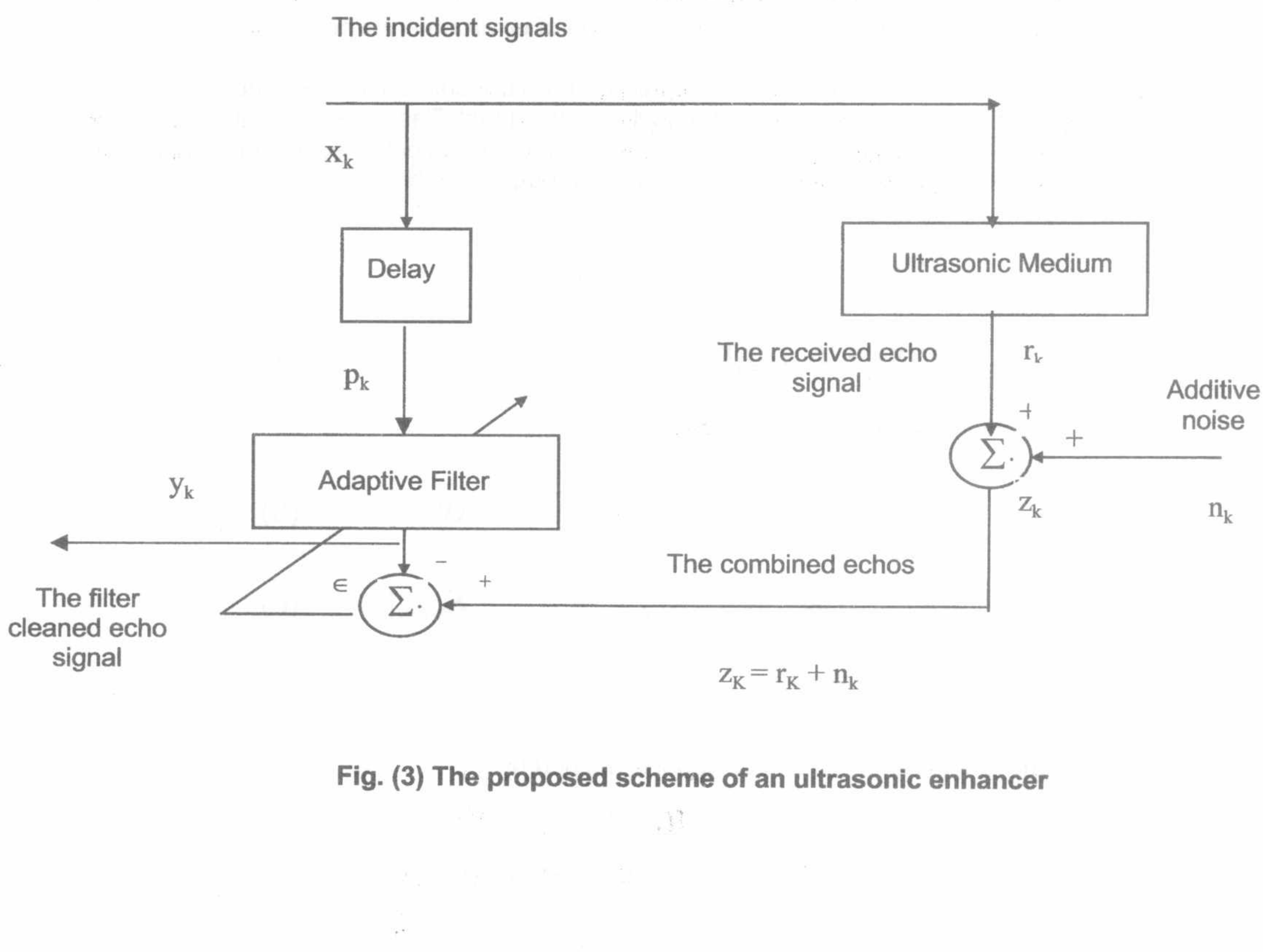

Fig. (3) The proposed scheme of an ultrasonic enhancer

The desired signal that is transmitted by the ultrasonic transducer can be expressed as: -

$$X_k = a\cos(\omega kT) \qquad (1)$$

Where: -

a denotes the signal amplitude
ω denotes the angular frequency
T denotes the sampling frequency

The reflected signals from the biological tissues can be written as: -

$$Z_k = r_k + n_k \qquad (2)$$

Where r_k is the reflected ultrasound signals due to the incident waves and n_k represents the additive noise due to the interference of environmental noise.

Thus the purpose of the adaptive filter module in the ultrasonic enhancer scheme is to produce a good estimate of the cleaned reflected echo signal. Then the filter output after convergence is considered as a good replica of the cleaned reflected echo signal and it is subtracted from the primary noisy signal. The filter output can be written as

$$y(k) = \sum_{i=0}^{N} W_i\, X(k-\Delta-i) \qquad (3)$$

or

$$y(k) = W^T(k)\, X(k-\Delta) \qquad (4)$$

The weight coefficient vector is defined as: -

$$W^T = [\, W_{0,k}\; W_{1,k}\; W_{2,k} \qquad W_{N,k}\,] \qquad (5)$$

$$X^T_{k-\Delta} = [\, X_{k-\Delta}\; X_{k-\Delta-1}\; X_{k-\Delta-2} \qquad X_{k-\Delta-N}] \qquad (6)$$

Then the error signal is written as: -

$$\varepsilon_k = Z_k - y_k \qquad (7)$$

Hence, the mean square of the output signal is defined by :-

$$E[\varepsilon^2(k)] = E[(Z_k(k) - y(k))^2] \qquad (8)$$

$$E[\varepsilon^2(k)] = E[(r_k(k) - y(k)+n_k(k))^2] \qquad (9)$$

V. The adaptation algorithm

The LMS adaptation is given by [2]:-

$$W(k+1)=W(k)+2\,\mu\varepsilon(k)\,X\,(k-\Delta). \qquad (10)$$

The main function of the design parameter (μ) is to control the adaptation speed and the stability of the adaptation algorithm [2].

The output signal to noise ratio can be expressed as:-

$$snro(dB)=10\,\log\,(E[r_k^2]/E([r_k-y_k]^2)). \qquad (11)$$

Also the input signal to noise ratio can be written as: -

$$snri(dB)=10\,\log\,(E[r_k^2]/E[n_k^2]). \qquad (12)$$

Then the improvement factor is calculated as:-

$$imp(dB) = snro(dB) - snri(dB) \qquad (13)$$

V. SIMULATION RESULTS: -

The performance of the proposed scheme depicted in Fig. (2) is evaluated through the computer simulation . The evaluation measures are characterized by the transient and steady state response. The transient response is described by learning curve while the steady state response is signified by the enhanced steady state output at different values of input signal to noise ratio.

The signal model is described by: -

$$X_k = a\cos(\omega kT) \qquad (1)$$

Also, the reflected echo signal which penetrates through tissue can be written as: -

$$r_k = \Psi_1{}^* X_k + \Psi_2{}^* X_{k-1} + \Psi_3{}^* X_{k-2} \qquad (2)$$

In our simulation we take $\Psi_1 = 0.99$, $\Psi_2 = 0.0007$, and $\Psi_3 = 0.001$.

The environmental noise (n_k) in this paper is considered as uniformly distributed random noise {-1,1}, of variance .

Hence the received noisy echo signal is expressed as :-

$$Z_k = r_k + n_k \qquad (3)$$

Fig. (4) indicates the incident wave and the reflected noisy echo signal.

Fig. (5) explains the steady state output signal of the adaptive filter after convergence. It is clear that the filter output signal is a good estimate of the original incident signals and it provides a 37.7 dB improvement factor in the output signal to noise ratio.

Fig. (6) demonstrates the dynamic behavior of the adaptive filter in both the transient and the steady state performance. It is apparent that the filter converges after 2800 samples.

The updating of the filter coefficients during the adaptation process is explained in Fig. (7). It is noticed that the filter coefficients successfully converge to the model coefficients after 2500 samples.

Fig. (8) presents the variation of the improvement factor interms of the input signal to noise ratio. It is clear that the improvement factor increases as the input SNR increases and it provides 37.7 dB improvement factor at input SNR of 2.4 dB.

VI. CONCLUSION:

It is obvious that the application of the adaptive filtering for enhancement of the ultrasonic signals (that are severely corrupted with the environmental noise) is interesting and attractive. The proposed ultrasonic enhancer provides a large improvement in the output signal to noise ratio. Moreover, the weight coefficients of the adaptive filter converge to the model coefficients. Therefore, the coefficients of the adaptive filter after convergence can be considered as important features for medical diagnostics of the tissue diseases, This will be considered in the future research.

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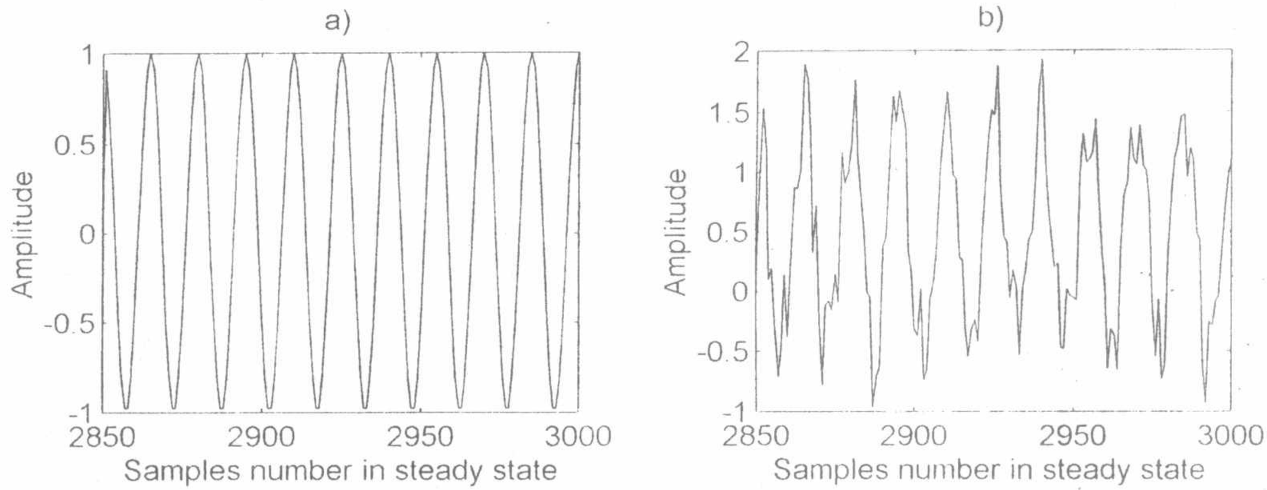
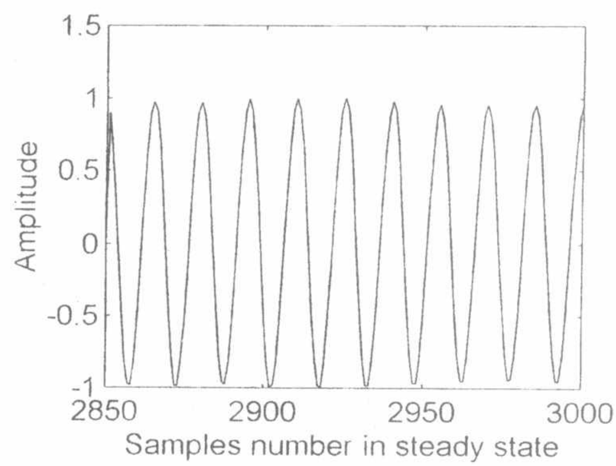


Fig. (4) Simulation results (a) denotes the incident wave, and (b) explains the reflected noisy signal.



Snrip (dB) = 2.4 snrop (dB) = 40 imf (dB) = 37.6
F = 1 MHz L = 3000 samples
N = 9 μ = 0.01

Fig. (5) The steady state output signal of the adaptive filter

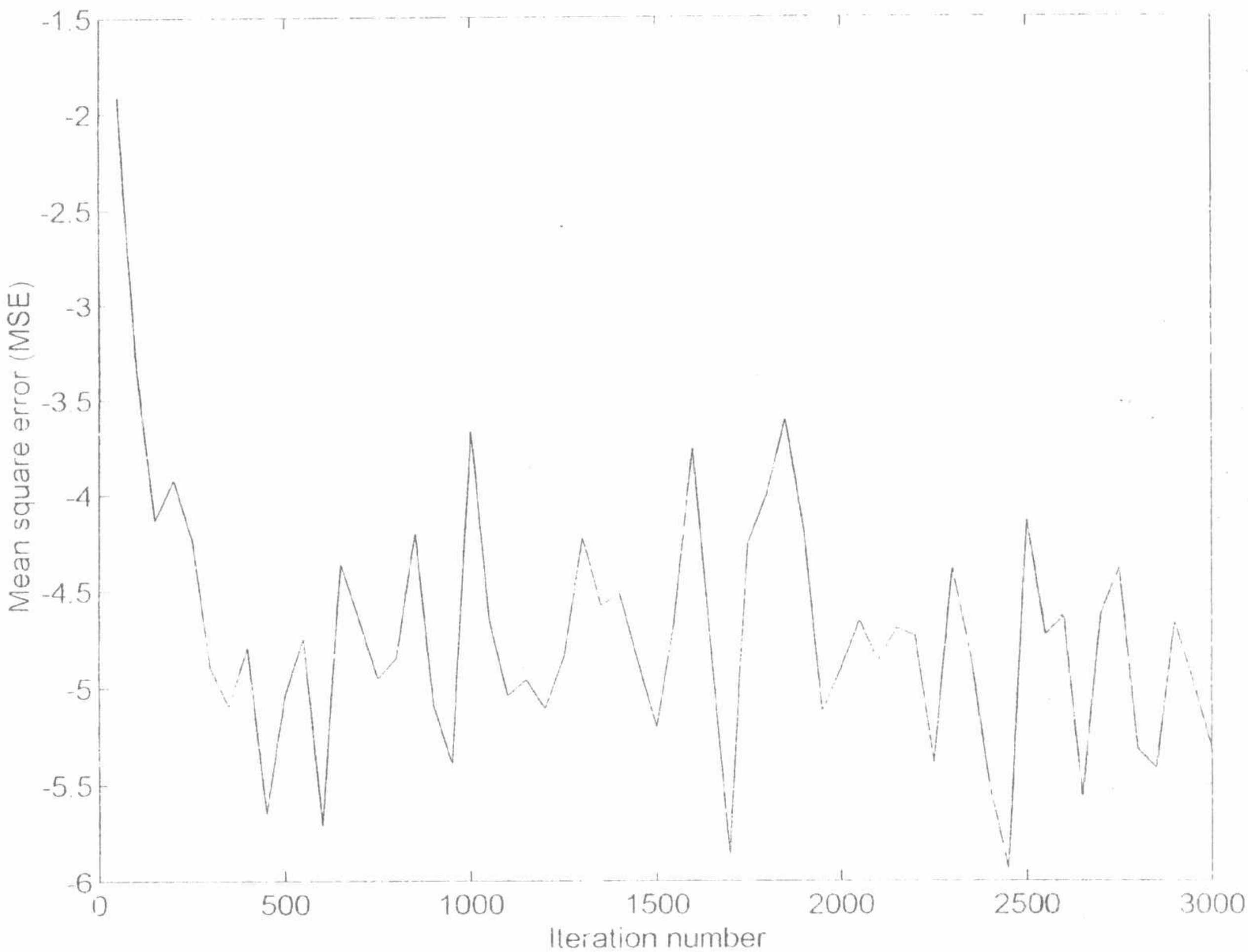


Fig. (6) Learning curve in dB where N=9 M=0.01 ISNR=2.5

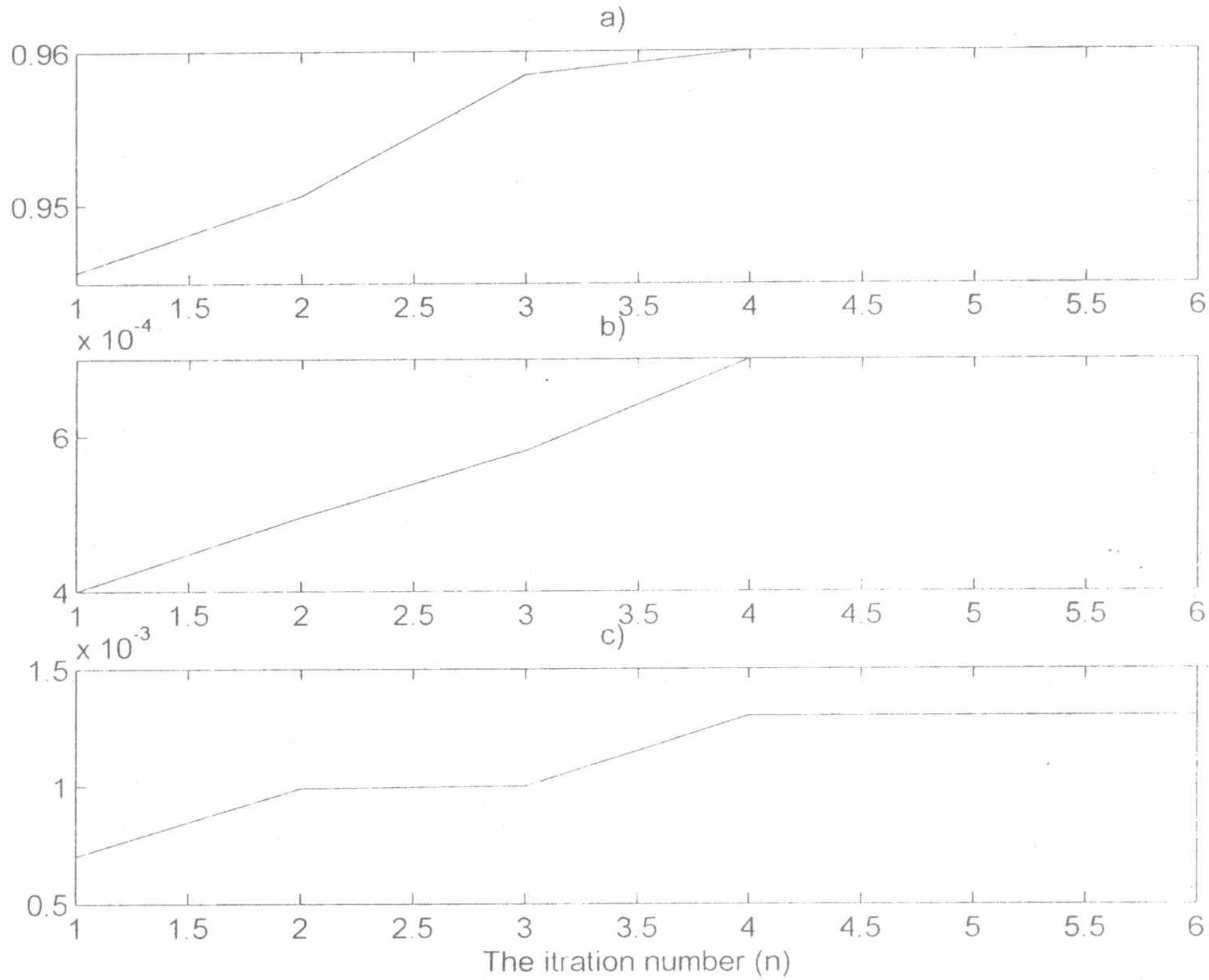


Fig. (7) The dynamic charactristics of filter coefficints (a) weight 1 ,(b) weight 2 , and (c) weight 3

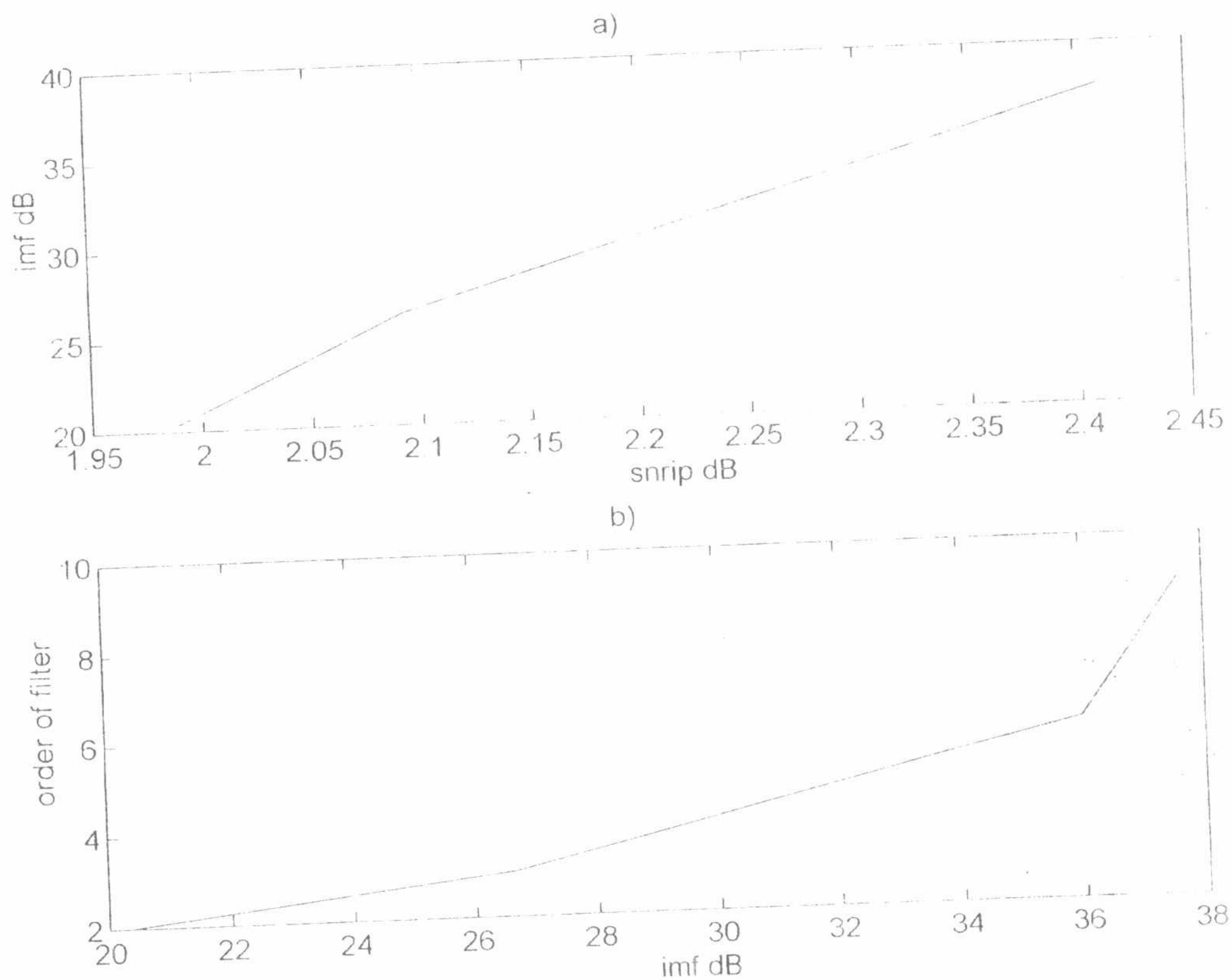


Fig. (8) Improvement factor in terms of (a) ISNR , and (b) order of filter