Audio Enhancement using Remez Exchange Algorithm with DWT

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Abstract: *Audio enhancement became important when noise in signals causes loss of actual information. Many filters have been developed and still improving. A highly optimized core discrete Remez part of the Parks-McClellan (PM) filter along with wavelet type discrete symlet filter been proposed in the paper. The proposed algorithm DWT-REA is experimented for two speech signals and efficiency is checked with calculation of MSE. Performance is also evaluated for different value of noise level. Proposed Algorithm is also compared with simple REA for seeing the improvement in recovered signal. Proposed algorithm can easily applicable in the field of speech enhancement.*

Keywords: *Remez Exchange Algorithm, Finite Impulse Response (FIR), Parks-McClellan (PM), DWT, Symlet Wavelet, Audio enhancement.*

I-Introduction

There are many applications where audio enhancement requires for example FM broadcasting or multimedia communication the quality of audio signal at the receiving end is never as was transmitted because of Noise or distortion or fading.

In order to enhance the audio quality of artificial reverberators, fast convolution techniques and hybrid reverberator structures have been explored by Andrea Primavera[1], Minje Kim propose the Probabilistic Latent Components Sharing (PLCS) is based on the probabilistic counterparts of Nonnegative Matrix Factorization model for collaborative audio enhancement, where common audio sources are constructed out of multiple noisy recordings of the same audio scene[2] Robert c. maher audio enhancement using nonlinear time-frequency filtering, they discussed that nonlinear and time-varying filters operate on the spectral representation in order to retain features that are attributable to the desired signal, such as human speech, while removing the features that are more likely to be due to the noise contamination[3].

The Remez exchange algorithm [4] is an optimization algorithm for audio enhancement that is commonly used in the design of FIR filters. It is popular because of its flexibility and computational efficiency. Also known as the Parks-McClellan algorithm [7], it works by converting the filter design problem into a problem of polynomial approximation. The optimal Chebyshev FIR filter [6] can often be found effectively using the Remez multiple exchange algorithms (typically called the ParksMcClellan algorithm when applied to FIR filter design). The Parks-McClellan/Remez algorithm also appears to be the most efficient known method for designing optimal Chebyshev FIR filters. The discrete wavelet transform (DWT) [8] is a linear transformation that operates on a data vector whose length is an integer power of two, transforming it into a numerically different vector of the same length.

Wavelets have an important application in signal denoising. After wavelet decomposition, the high frequency sub bands [8] contain most of the noise information and little signal information. properties of Discrete wavelet transforms[5] were employed to recover a signal from the signal with noise. The process of filtering can be broken into further steps which are: Analysis, Applying wavelet transform, Analysis Step

Selecting an appropriate wavelet was a very important task in this step. The wavelet chosen should be similar to the signal that has to be filtered to give the best possible results, applying wavelets to filter out the signal, Parks-McClellan or remez exchange based filtering approach gives a filtered signal with small amount of noise present that small amount can be negligible in some application but there are application like secure data communication, multiplexed broadcasting, real time digital data communication where noise cannot be ignored. So a filter which can remove maximum noise and have high SNR, low BER and low MSE is need of the communication world. Thus, Remez exchange based filtering adding with wavelet filter approach gives us a quite efficient denoised audio signal.

II-Proposed Algorithm DWT-REA

The REA Algorithm is implemented using the following steps:

1. Initialization: Choose an extremal set of frequencies $\{\omega_i^{(0)}\}$.
2. Finite Set Approximation: Calculate the best Chebyshev approximation on the present extremal set, giving a value $\delta^{(m)}$ for the min-max error on the present extremal set.
   $P^m(\omega) \approx \sum_{k=0}^{m-1} c_k T_k(\omega) - \frac{1}{2}c_0$ ... ... (1)
   Where c_k is the chebyshev coefficient and T_k is the chebyshev polynomial
3. Interpolation: Calculate the error function $E(\omega)$ over the entire set of frequencies Ω.
   $|P^m(\omega) - f^m(\omega)| = E^m(\omega)$ ... ...(2)
   $P(\omega)$ is the approximating polynomial, $f(\omega)$ is the actual function.
4. Look for local maxima of $|E^{(m)}(\omega)|$ on the set Ω.
5. If $\max_{(\omega\varepsilon\Omega)}|E^{(m)}(\omega)| > \delta^{(m)}$, then update the extremal set to $\{\omega_i^{(m+1)}\}$ by picking new frequencies where $|E^{(m)}(\omega)|$ has its local maxima. Make sure that the error alternates on the ordered set of frequencies. Return to Step 2 and iterate.
6. If $\max_{(\omega\varepsilon\Omega)}|E^{(m)}(\omega)| \leq \delta^{(m)}$, then the algorithm is complete. Use the set $\{\omega_i^{(0)}\}$ and the interpolation formula to compute an inverse discrete Wavelet transform to obtain the filter coefficients.

Figure 1 presents the modules in proposed work Next is DWT-REA section it is proposed work here first wavelet filtering module filter the noisy signal with wavelet which is type 6 symlet (sym6) which performs an interval dependent denoising of the noisy signal, using a wavelet decomposition at the level '5' with a wavelet which name is 'sym6'and perform soft thresholding. The family function of wavelet can define as

$\varphi_{a,b}(t) = \frac{1}{\sqrt{a}}\varphi(\frac{t-b}{a})$ ... ... (3)

If $\varphi_{a,b}(a > 0, b \in IR)$,

For symlet type 6 the filter coefficients computed from the equation 2 are:-

-0.00551593375469, 0.00124996104639, 0.03162528132994,-0.01489187564922,-0.05136248493090, 0.23895218566605, 0.55694639196396, 0.34722898647835,-0.03416156079324,-0.08343160770584 0.00246830618592 0.01089235016328

Next type 6 REA is a Parks-McClellan optimal equiripple FIR filter design, FIR filter which has the best approximation to the desired frequency response described by F and A in the minimax sense. F is a vector of frequency band edges in pairs, in ascending order between 0 and 1. 1 corresponds to the Nyquist frequency or half the sampling frequency. At least one frequency band must have a non-zero width. At least one frequency band must have a non-zero width. A is a real vector the same size as F which specifies the desired amplitude of the frequency response. In present work because denoising is our aim F is chosen [0 0.14 0.15 0.16 0.17 1] and A is [1 1 1 1 1 1] the value of F can be vary as per the input signal. The order of FIR filter is '40', As the order 40 in FIR-PM filter gives delay of 40/2 samples hence it is requires to have 20 sample advance the output signal. Mean square error can be calculated as-

$$MSE = \frac{\sum_{c=0}^{c=C}(\sum_{r=0}^{r=R}(Xrc - Yrc)^2)}{R*C} \quad \ldots\ldots\ldots\ldots\ (4)$$

Here R in the number of Row and C is the number column. x is the input noisy signal and y is the output filtered signal.

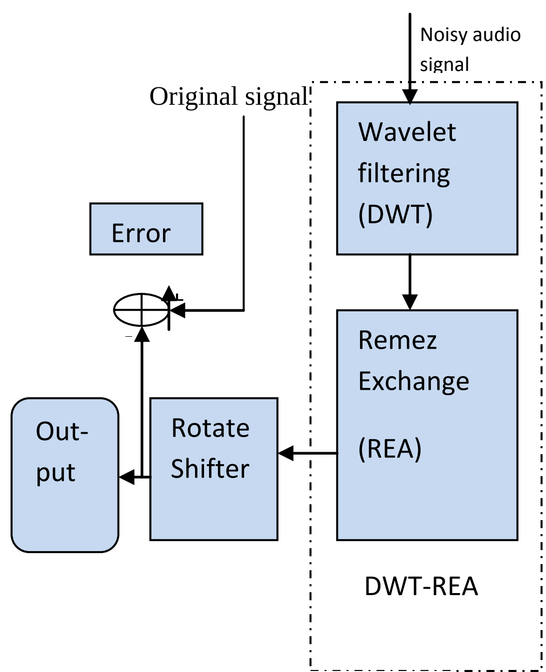

Fig.1: the proposed design algorithm

III-Experimental Results

The results is been observed for two different input signal a chirp signal of 25Hz to 125Hz and audio file of 44200Hz sampling frequency with different AWGN noise value in 'db'. Different Noise needed for testing all type of possible real life situations.

Proposed design DWT-REA the order of FIR is 40, type 6 of REA and symlet order 6 with 5 level decomposition wavelet fitter is been selected.

Case study-1: for chirp signal figure 2 shown below shows actual input chirp signal and its 30db awgn noisy signal

Figure 3 shown below shows analytical comparison of given input chirp signal and enhanced filtered output signal.

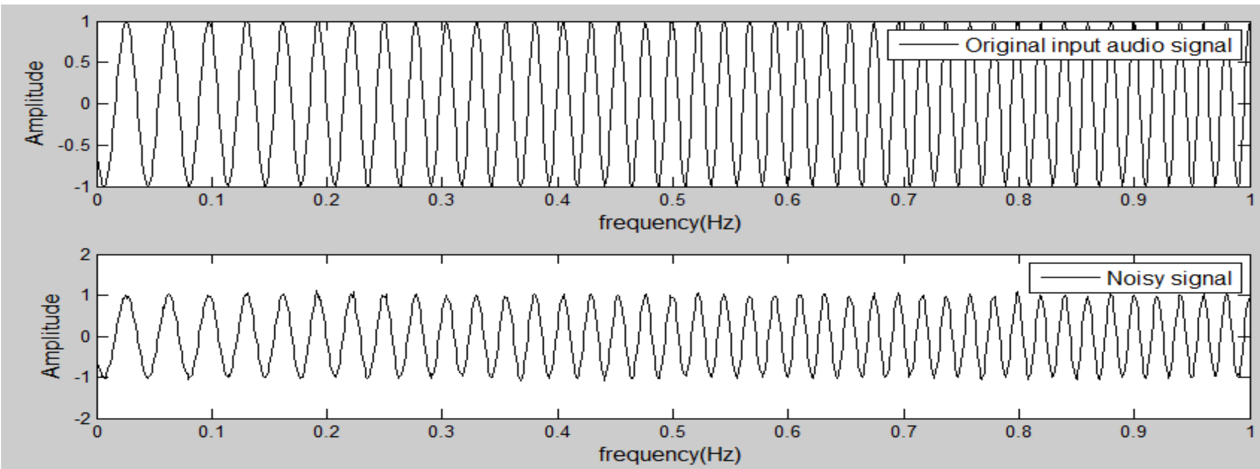

Fig. 2: the original chirp signal and noisy signal

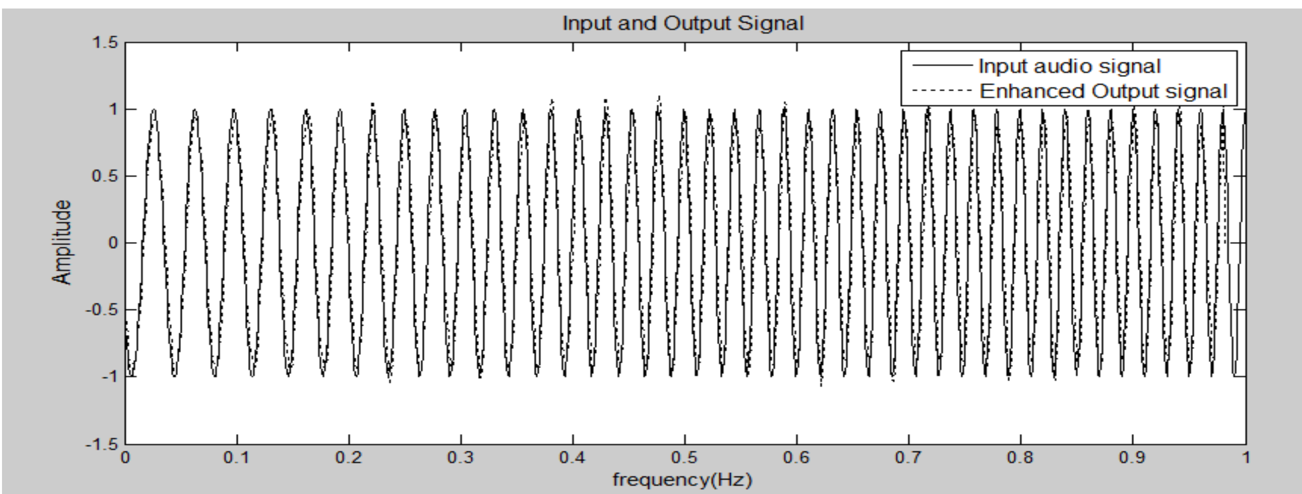

Fig. 3: Original chirp and filtered enhanced output chirp signal

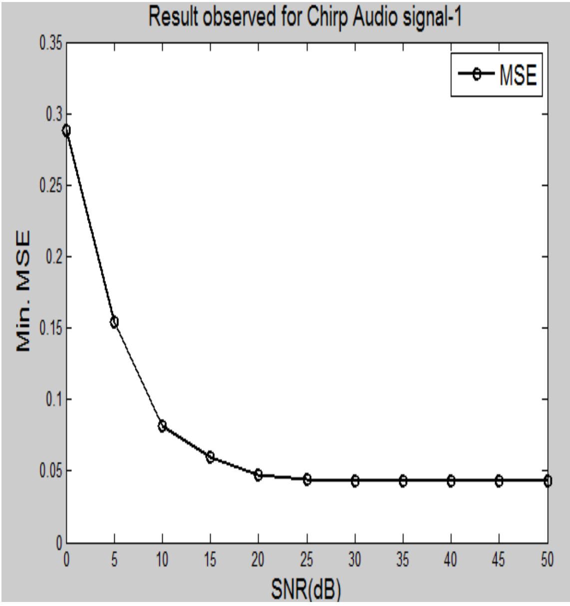

Figure 4 shown below shows a comparative analytical plot which is been develop for different noise quantity in input and output observed, the comparison is been done as mean square Error between chirp input and chirp output.

Fig. 4: MSE for different noise value in Chirp signal

Table 1: MSE observed in chirp for different Noise level

S. No.	SNR (dB)	Min.MSE
1	0	0.2879
2	5	0.1546
3	10	0.0813
4	15	0.0597
5	20	0.047
6	25	0.0441
7	30	0.0427
8	35	0.0429
9	40	0.0431
10	45	0.0432
11	50	0.0433

The MSE for chirp signal in worst case obtain is 0.2879.

Case study-2: for audio signal-2 figure 5 shown below shows actual input audio signal and its 30db awgn noisy signal.

Figure 6 shown below shows analytical comparison of given input audio signal and enhanced filtered output signal.

Figure 7 shown below shows analytical comparison of given input audio signal and enhanced filtered output signal.

Table 2: MSE observed in Audio for different Noise level

S. No.	SNR(dB)	Min. MSE
1	0	0.0105
2	5	0.0078
3	10	0.0055
4	15	0.0038
5	20	0.0029
6	25	0.0024
7	30	0.0022
8	35	0.0021
9	40	0.0021
10	45	0.0021
11	50	0.0021

The MSE for Audio signal in worst case obtain is 0.0105.

Figure 8 shown below shows a comparative analytical plot which is been develop for different noise quality in input and output MSE observed, the comparison is been done as MSE between audio input and audio output.

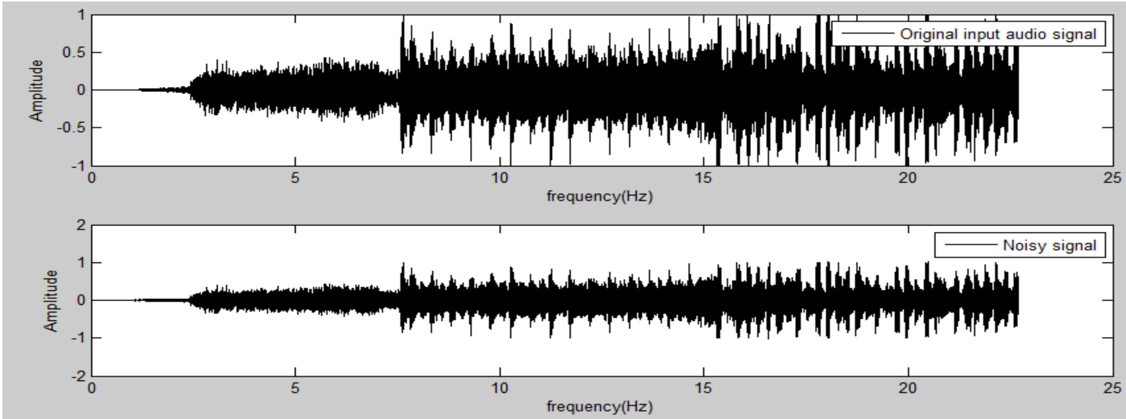

Fig. 5: the Audio & noisy signal

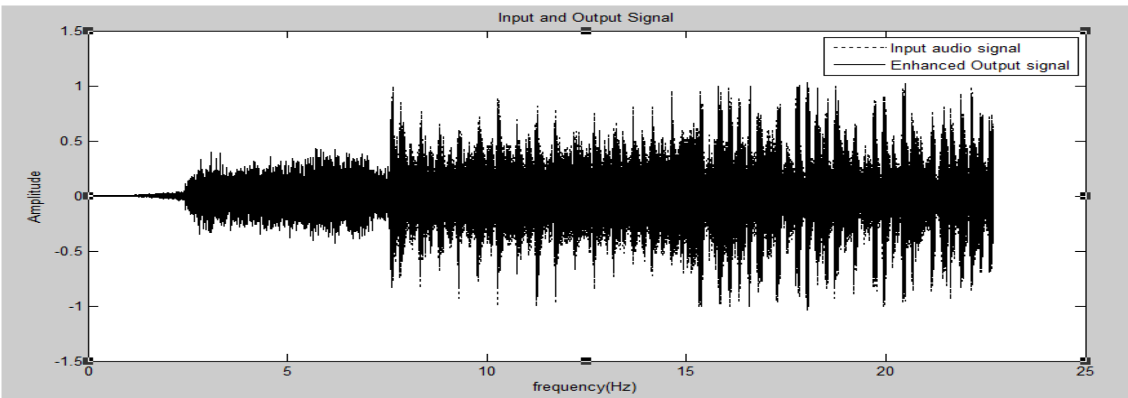

Fig. 6: the audio input signal and filtered enhanced output

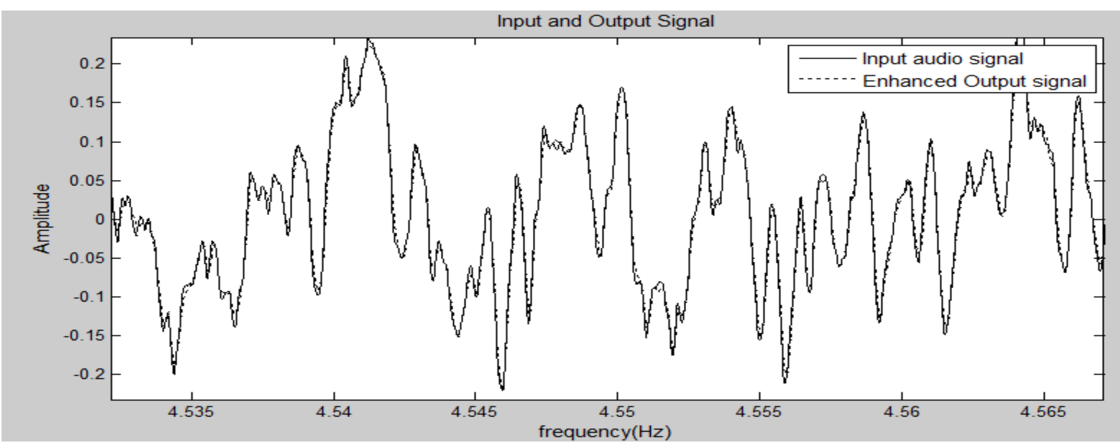

Fig. 7: the audio input signal and filtered enhanced output

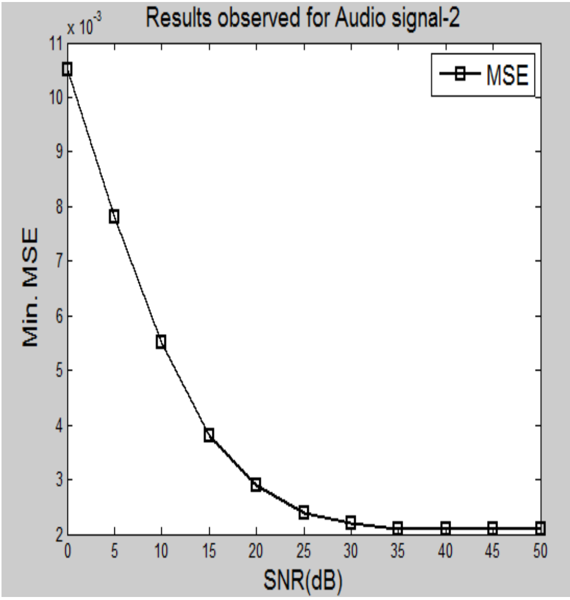

Fig. 8: MSE for different noise value in Audio signal

Comparison of DWT-REA with REA: the comparison is been done as MSE between REA and proposed DWT-REA algorithm as shown in table 3 for an audio signal.

Table 3: MSE observed in DWT-REA and REA

S. No.	Algorithm	SNR(dB)	Min. MSE
1	REA	35	0.0442
2	DWT-REA	35	0.0021

IV- Conclusion

DWT-REA Algorithm is successfully implemented and experimented for audio signals. Performance of the model shows quite good denoising of the recovered signal. Remez exchange algorithm with symlet wavelet function gives quite efficient minimum MSE which is compared with algorithm REA without DWT and justified better for different noise level. This proposed algorithm can be applied anywhere in the field of audio enhancement.

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