SIGNIFICANCE OF COMPLEX GROUP DELAY FUNCTIONS IN SPECTRUM ESTIMATION

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Abstract:

This paper presents a method of spectrum estimation using second order group delay functions derived from the phase of the Fourier Transform (FT). The results obtained from the proposed method are compared with that of first order group delay function spectral estimation. This method provides better resolution with reduced variance and also suppresses the spikes generated due to noise in the spectrum compared to first order group delay functions spectral estimation. The spectral estimation is obtained using this method, the resolution properties of the periodogram estimation are preserved while the variance is reduced. Variance caused by the side lobe leakage due to windows and additive noise is significantly reduced even in the spectral estimate obtained using a single realization of the observation peak. This method works even for high noise levels (SNR = 0 dB or less).

Keywords

Complex Group Delay, Second Order Group Delay, spectrum estimation, Fourier Transform, Periodogram, Resolution, side lobe leakage

Introduction:

The objective of this paper is to explore an approach to spectrum estimation from the Fourier transform phase of the signal. The method described is based on the properties of the second order derivative of Fourier Transform phase function. Various attempts [1-3] have been made to demonstrate the spectrum estimation based on the properties of the negative derivative of the FT phase function, also called group delay function. The most important properties of the group delay function are the additive and high resolution properties [2]. Here the resolution refers to the sharpness of the peaks in group delay function, which is due to FT magnitude function behavior of the group delay function.

Traditionally, the phase spectrum of the signal has been ignored, primarily because only the principal values of the phase can be estimated from the Fourier transform. For the phase to be used, the phase function will have to be unwrapped to produce a continuous estimate [4]. On the other hand, the group delay function [5] (defined as the negative derivative of the phase function), which has properties similar to the phase, can be computed directly from the signal.

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Group delay is an important feature of the signal that can help in enhancing the signal quality in noisy conditions [6]. Previous research works have revealed the usefulness of group delay in many applications. Recent studies on speech perception have revealed the importance of the phase of speech signal [7-8]. In order to overcome the problem of spikes in group delay, some researchers have suggested solutions such as modified group delay [3] and product spectrum [9]. Group delay is also found to be a good domain for formant tracking [10-11].

A new function called complex I-Order and II-Order Group delay spectrum estimation functions based on the derivatives of the FT phase has been proposed for spectrum estimation. The proposed complex I-Order and II-Order Group delay estimations are applied for both sinusoids in noise as well as for narrow-band autoregressive processes to extract useful spectral information and to compare the same with the results obtained using the group delay functions proposed [1-2]. It is observed that, the proposed complex II-Order Group delay estimation method reduces the noise levels to large extent and also significantly reduces side lobe leakage due to windows and additive noise.

This paper is organized as follows. Section 2 briefly discusses the major related work. Section 3 presents the formulation of Complex I-Order and II-Order Group Delay Functions. Section 4 discusses the Algorithm for computing II-order group delay functions taking examples. Section 5 speaks about the results produced using the proposed method. Section 6 concludes the paper.

Group Delay

The group delay function is defined as the negative derivative of the Fourier transform phase of a signal [1-2, 5]. For a minimum phase signal, the group delay computed from the magnitude spectrum of the Fourier transform is equal to that computed from the phase spectrum [9, 12].

Computation of the group delay function of a real signal is difficult due to various reasons. The most important one is due to the wrapping of the phase function. This is because the phase function of a discrete time signal, results in discontinuities in multiples of $\pm\pi$. This problem may be overcome by computing the group delay function $\tau(\omega)$ directly from the signal $x(n)$ as follows [5, 13]:

$$X(\omega) = \sum_n x(n)e^{-j\omega n} \qquad (1)$$

The X (ω) as a function of magnitude and phase can be expressed

$$X(\omega) = |X(\omega)|e^{j\Phi(\omega)} \qquad (2)$$

$$here\ |X(\omega)| = \sqrt{X_R^{\,2}(\omega) + X_I^{\,2}(\omega)}$$

$$\Phi(\omega) = Tan^{-1}\left(\frac{X_I(\omega)}{X_R(\omega)}\right)$$

The group delay $\tau(\omega)$ is defined as [5, 11-16]

$$\tau(\omega) = -\frac{d\Phi(\omega)}{d\omega} \qquad (3)$$

To avoid unwrapping, another method [4, 9-11, 16] is used to calculate the group delay directly as:

$$\log X(\omega) = \log(|X(\omega)|) + j\Phi(\omega) \qquad (4)$$

Equation (3) can be simplified as [5,16]

$$\tau(\omega) = -\operatorname{Im}\left(\frac{[d\log X(\omega)]}{d\omega}\right) \qquad (5)$$

Group delay $\tau(\omega)$ can be computed directly from (2) and (3) using the procedure [6, 17]

$$\tau(\omega)=\left\{\frac{X_R(\omega)\ Y_R(\omega)\ \ +X_I(\omega)Y_I(w)}{|X(\omega)|^2}\right\} \tag{6}$$

where

X_R = Real part of the Fourier Transform of x(n)
X_I = Imaginary part of the Fourier Transform of x(n)
Y_R = Real part of the Fourier Transform of nx(n)
Y_I = Imaginary part of the Fourier Transform of nx(n)

3. Formulation of Complex Group Delay Functions

Complex group delay function can be formulated from the definition of the Fourier Transform (1) as follows

$$X(\omega)=|X(\omega)|e^{j\Phi(\omega)} \tag{7}$$

In equation (7), $|X(\omega)|$ is the frequency magnitude response of the filter, $\Phi(\omega)$ is the filter phase response and ω is continuous frequency measured in radians/seconds. Taking derivative of $X(\omega)$ with respective to ω on both sides of equation (7).

$$\frac{dX(\omega)}{d\omega}=|X(\omega)|e^{j\Phi(\omega)}j\frac{d\Phi}{d\omega}+e^{j\Phi(\omega)}d\frac{|X(\omega)|}{d\omega}$$

$$\frac{dX(\omega)}{d\omega}=jX(\omega)\frac{d\Phi}{d\omega}+\frac{|X(\omega)|e^{j\Phi(\omega)}}{|X(\omega)|^2}\left[X_R\frac{dX_R}{d\omega}+X_I\frac{dXI}{d\omega}\right]$$

$$\frac{dX(\omega)}{d\omega}=jX(\omega)\frac{d\Phi(\omega)}{d\omega}+\frac{X(\omega)}{|X(\omega)|^2}\left[X_RY_I-X_IY_R\right] \tag{8}$$

After some simple algorithmic manipulations the equation (8) becomes

$$\left[j\left(\frac{dX(\omega)}{d\omega}\right)\Big/X(\omega)\right]=-\frac{d\Phi(\omega)}{d\omega}+j\frac{\left[X_RY_I-X_IY_R\right]}{|X(\omega)|^2}$$

$$\left[j\left(\frac{dX(\omega)}{d\omega}\right)\Big/X(\omega)\right]=\tau_{R_1}(\omega)+j\tau_{I_1}(\omega) \tag{9}$$

$$\tau(\omega)=\tau_{R_1}(\omega)+j\tau_{I_1}(\omega) \tag{10}$$

From the above (10) the Group Delay term $\tau(\omega)$ now onwards called I-Order Group Delay appears as a complex quantity of which the real part $\tau_{R_1}(\omega)$ is the Group Delay obtained from the traditional definition and the imaginary term $\tau_{I_1}(\omega)$ is new to the literature. The real and imaginary terms form more general expression for the Group Delay called complex group delay $\tau(\omega)$. It is observed from the above formula, the dimensions of the $\tau_{I_1}(\omega)$ are also same with dimensions of $\tau_{R_1}(\omega)$.

The equation (10) appears as a more general expression for the computation of the Group Delay called complex I-Order Group Delay when compared with the Real Group Delay obtained from the definition of the equation (3). Using the equation (10) it can be seen the better results from the following analysis.

Therefore from (9-10) the Real and imaginary terms of Complex I-Order Group Delay $\tau(\omega)$ are related as.

$$\operatorname{Re}al\left[j\left(\frac{dX(\omega)}{d\omega}\right) \Big/ X(\omega) \right] = \tau_{R_1} = \frac{X_R Y_R + X_I Y_I}{|X(\omega)|^2} \tag{11}$$

$$imag\left[j\left(\frac{dX(\omega)}{d\omega}\right) \Big/ X(\omega) \right] = \tau_{I_1} = \frac{X_R Y_I - X_I Y_R}{|X(\omega)|^2} \tag{12}$$

The formulation of the proposed complex II-order Group Delay method is being derived by taking the derivative of (10) with respect to ω and after performing some simple algebraic manipulations, it can be shown

$$\frac{d\tau(\omega)}{d\omega} = \left[\frac{d\tau_{R_1}(\omega)}{d\omega}\right] + j\left[\frac{d\tau_{I_1}(\omega)}{d\omega}\right] \tag{13}$$

$$\frac{d\tau_{R_1}(\omega)}{d\omega} = \left[\frac{X_R(Z_I - 2\tau_{R_1} Y_I) - X_I(Z_R - 2\tau_{R_1} Y_R)}{(X_R{}^2 + X_I{}^2)}\right] = \tau_{R_2} \tag{14}$$

$$\frac{d\tau_{I_1}(\omega)}{d\omega} = \left\{\frac{|Y(\omega)|^2 - \left(X_R Z_R + X_I Z_I\right)}{|X(\omega)|^2}\right\} - 2\tau_{I_1}^2 = \tau_{I_2} \tag{15}$$

Here the quantity $\frac{d\tau(\omega)}{d\omega}$ is the Complex II- order Group Delay with $\frac{d\tau_{R_1}(\omega)}{d\omega}$ and $\frac{d\tau_{I_1}(\omega)}{d\omega}$ as the real and imaginary terms respectively and the terms Z_R and Z_I refers

Z_R = Real part of the Fourier Transform of $n^2x(n)$

Z_I = Imaginary part of the Fourier Transform of $n^2x(n)$

The other terms $X_{R,}$ $X_{I,}$ $Y_{R,}$ and YI have their usual meaning described in section-2.

4. Illustrations:

Two types of problems [1] are considered for comparison of signals.

Example1: Autoregressive process in noise (estimation of the AR spectrum)

$$x_1(n) = s(n) + u(n)$$

$$s(n) = -\sum_{k=1}^{4} a_k s(n-k) + Ge(n) \qquad (16)$$

Where the excitation e(n) is a white Gaussian noise of variance unity and u(n) is an additive noise with variance dependent upon the coefficients are:a_1=-2.760,
a_2 = 3.809, a3 = -2654, and a_4=0,924.

Example 2: Two sinusoids in noise (estimation of frequencies of the sinusoids)

$$x_2(n) = \sqrt{10}\exp[j2\pi(0.10)n] + \sqrt{20}\exp[j2\pi(0.15)n] + u(n)$$

Where u(n) is additive white Gaussian noise with the variance dependent upon the SNR. These examples are similar to the ones used in [2,7] for discussion of periodogram estimates.

We assume a sampling frequency of 10 kHz and number of samples N=512 for example-1, and example-2. Different realizations of x_1(n) and x_2(n) are obtained by using different noise sequence each time. The derivatives of the Real and imaginary parts of the complex II-order Group Delay function are being calculated using (14) and (15) respectively.

The procedure for computing the complex II-order Group Delay function and the estimated spectrum for a given sequence of samples x(n) is given in sections 4.1.

4.1 **Algorithm for computing II-order group delay functions**

1. Let x (n) be the given M-point causal sequence compute [14] y (n) = nx(n).
2. Compute the N-pt (N>>M) Discrete Fourier Transform (DFT) X (k) and Y (k) of the sequences x(n) and y(n) respectively k=0,1,…..,N-1.
3. Compute cepstrally smoothed spectrum S(k) of $|X(k)|^2$
4. Compute the zero spectrum z(k) by dividing $|X(k)|^2$ by S(k).
5. Compute the modified group delay function $\tau_0(k)$ as

$$\tau_0(k) = \frac{X_R(k)Y_R(k) + X_I(k)Y_I(k)}{|X(k)|^2}\hat{Z}(k), k = 0,1,....,N-1.$$

6. Compute the derivatives of real and imaginary parts of group delay function of equation (10) as

$$\frac{d\tau_{R_1}}{d\omega} = \left[\frac{X_R(Z_I - 2\tau_{R_1}Y_I) - X_I(Z_R - 2\tau_{R_1}Y_R)}{(X_R{}^2 + X_I{}^2)}\right]$$

$$\frac{d\tau_{I_1}}{d\omega} = \left\{ \frac{|Y(\omega)|^2 - \left(X_R Z_R + X_I Z_I\right)}{|X(\omega)|^2} \right\} - 2\tau_{I_1}^2$$

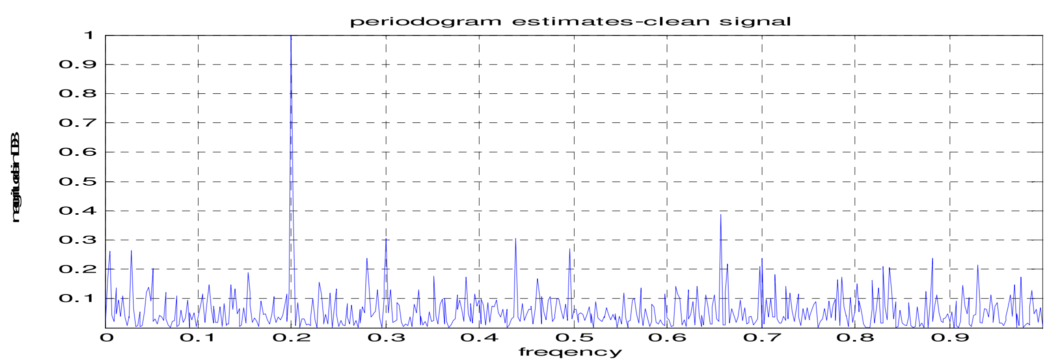
5. Results & Discussion

Figs. 1-7 give the periodogram, complex I-order and II- order Group Delay functions of the noisy signal (SNR = -15 dB) of example 2. Figs. 1(a), 2(a), 3(a), 4(a), 5(a), 6(a) and 7(a) show the plots for a single realization of clean data. Figs. 1(b), 2(b),3(b), 4(b), 5(b), 6(b) and 7(b) show the plots for 50 realizations of noisy data. Figs. 1(c), 2(c),3(c), 4(c), 5(c), 6(c) and 7(c) show the averaged plots.

Figs. 8-13 give the autoregressive process complex I & II- order Group Delay function from the noisy signal (SNR = -15 dB) of example-1. Figs. 8(a), 9(a),10(a), 11(a), 12(a), and 13(a) show the plots for a single realization of clean data. Figs. 8(b), 9(b),10(b), 11(b), 12(b), and 13(b) show the plots for 50 overlaid realizations of noisy data. Figs. 8(c), 9(c),10(c), 11(c), 12(c), and 13(c) show the averaged plots.

Reduction of variance by averaging several periodograms introduces large bias [15]. The variance is significantly reduced in the spectrum estimated by group delay method The averaging reduces the dynamic range in periodogram whereas averaging the estimated spectrum from group delay does not seem to significantly affect the dynamic range (Figs. 7(a) and (c)). We have also applied the proposed method for autoregressive process successfully. The results are shown in the plots given in Figs. 8-13 for SNR = -15 dB. The proposed method works well even for estimating sinusoids in the presence of noise. The same general conclusions as valid for the autoregressive process hold good for sinusoidal process also.

Fig. 14 and 15 gives a comparison of the performance of our proposed method of spectrum estimation with I-order existing method proposed by [1]. The data consists of 512 samples of AR process in noise (single realization). Note that the group delay function method preserves the resolution properties of the periodogram, with much less variance, even for low SNR. Unlike the periodogram method, the group delay method restores the dynamic range of the AR process even at high noise levels. Model-based techniques fail to resolve the peaks at high noise levels (SNR <15 dB). If the order of the model is increased, more spurious peaks will be generated. It is interesting to note that even for a single realization, the dynamic range is almost restored and the fluctuation due to noise and data windows are almost absent in the estimated spectrum using the proposed group delay method.



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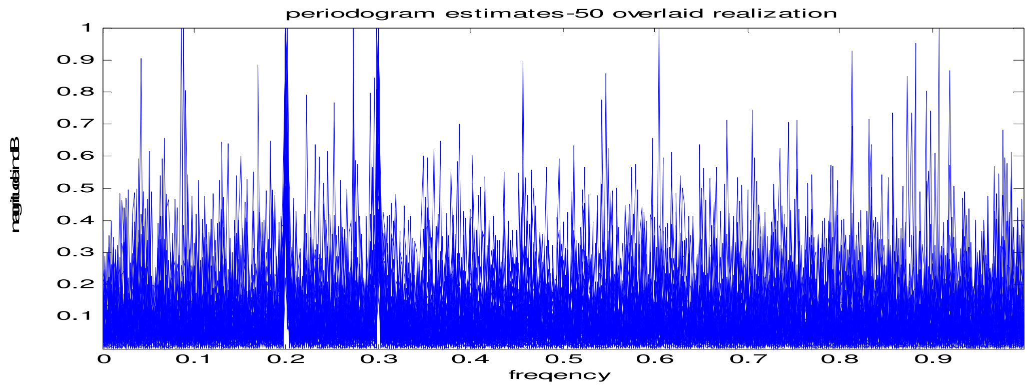

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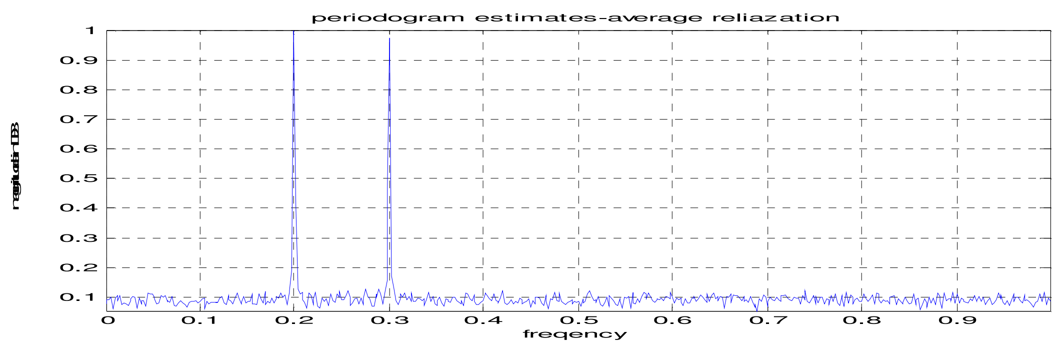
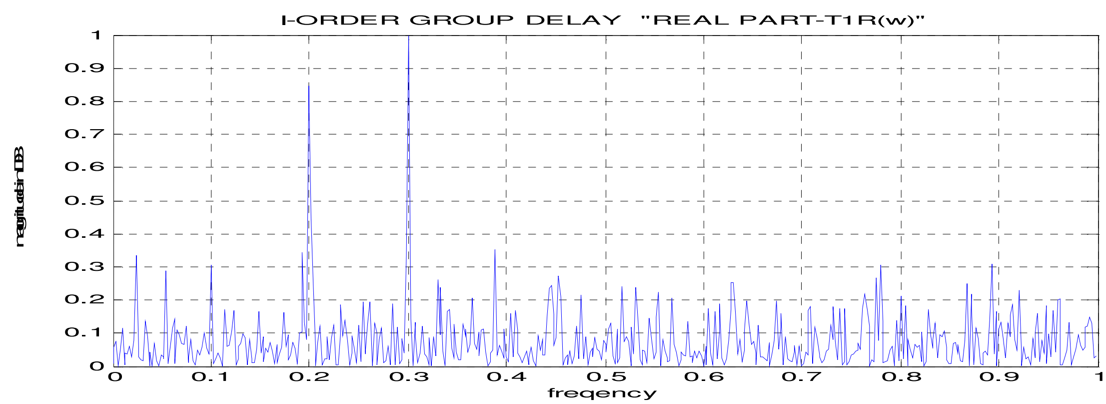


(c)

Fig.1 Periodogram Estimation of signals in noise(N=512SNR=-15dB). (a) single realization(clean signal).(b) 50 overlaid realizations.(c) average realization.



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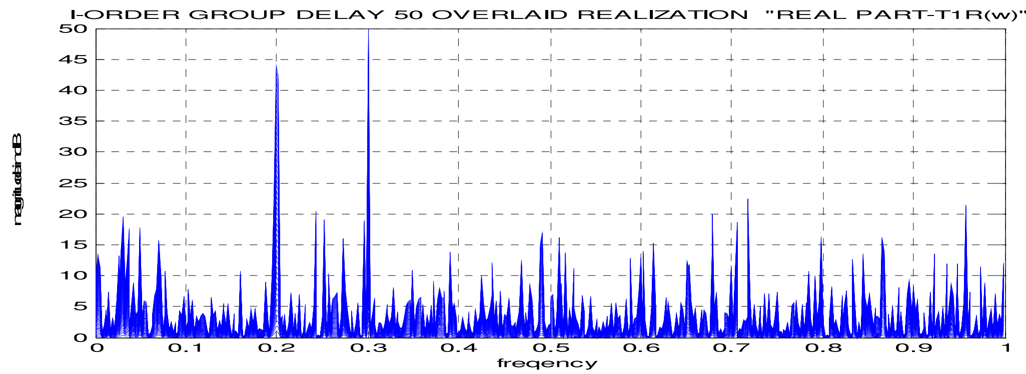

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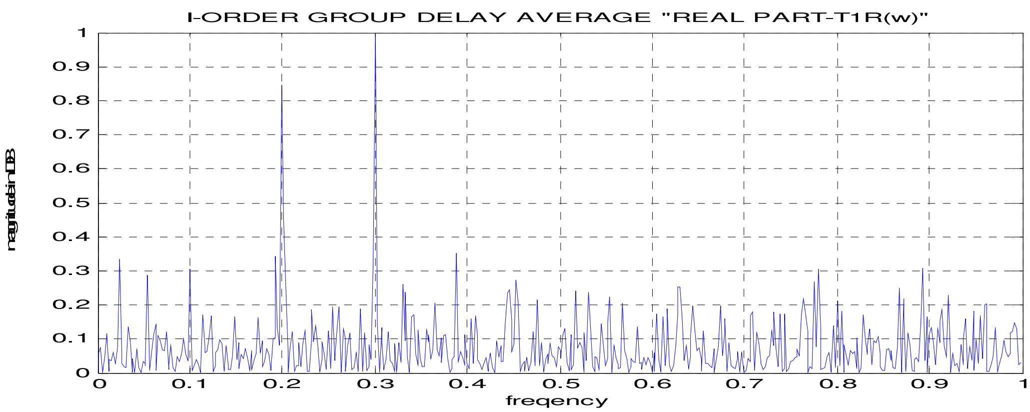
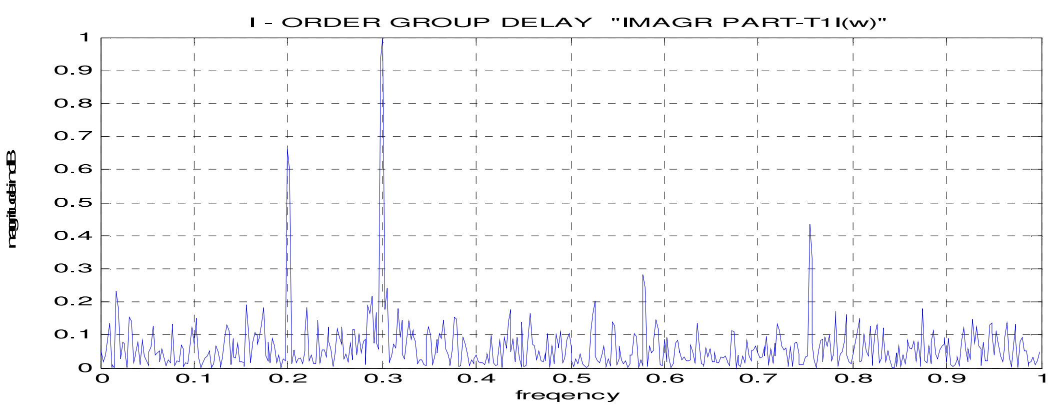


(c)

Fig.2 Estimated I-order real part of the group delay function in noise (N=512,SNR=-15dB)
(a) single realizations (clean signal).(b) 50 overlaid realizations.(c) average realizations.



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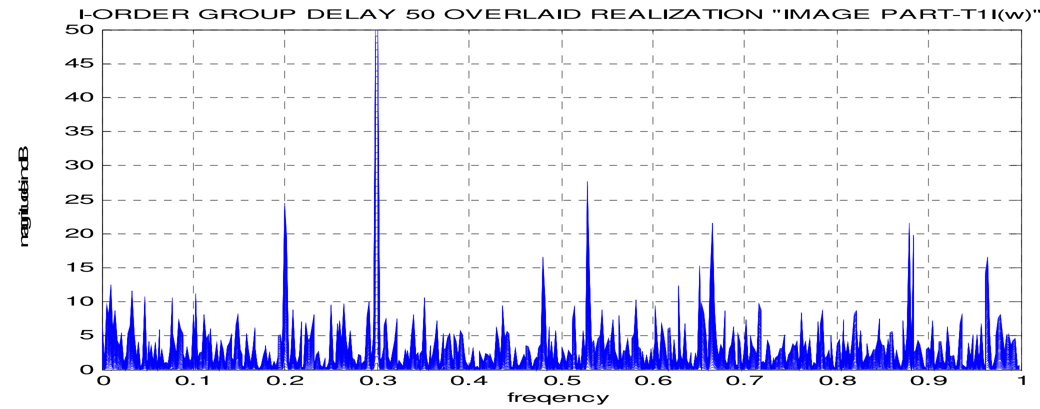

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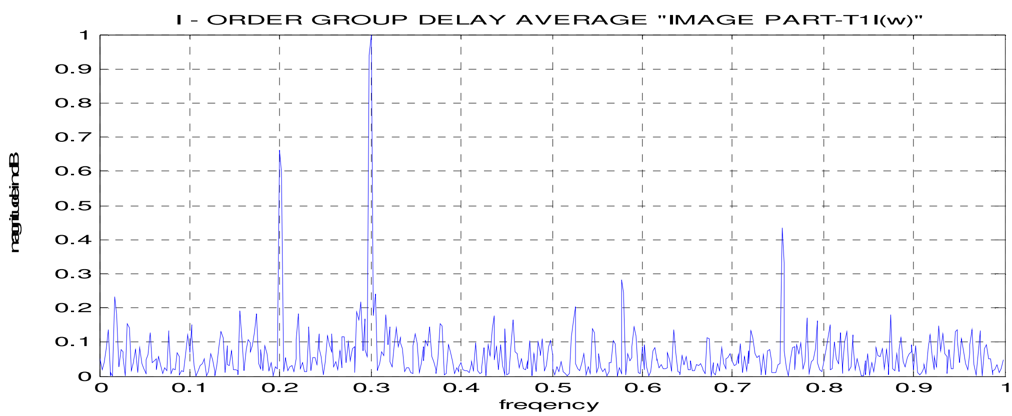
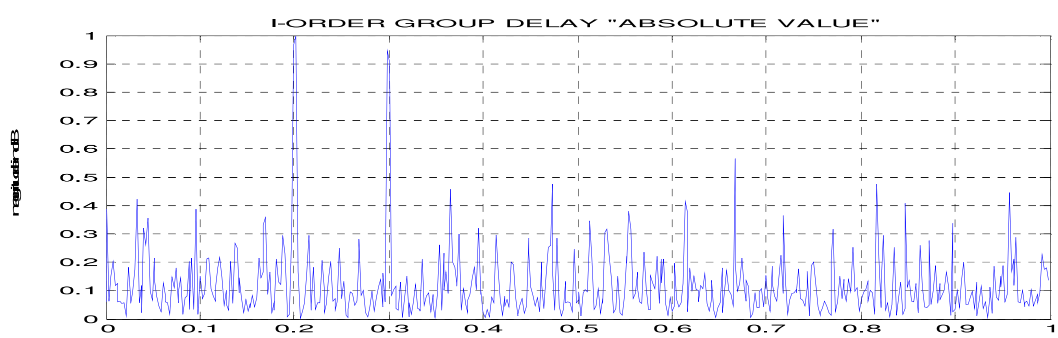


(c)

Fig.3 Estimated I-order Imaginary part of the group delay function in noise (N=512, SNR= -15dB). (a)Single realizations (clean signal).(b) 50 overlaid realizations. (c)Average realizations.



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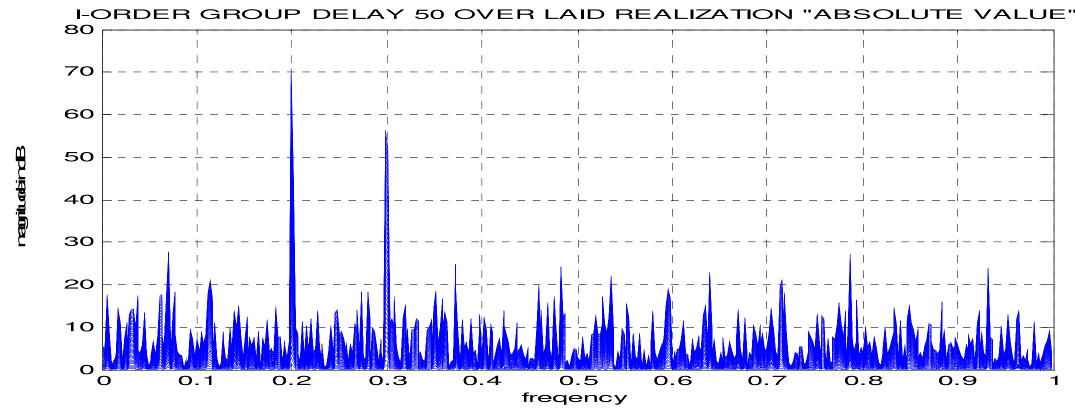

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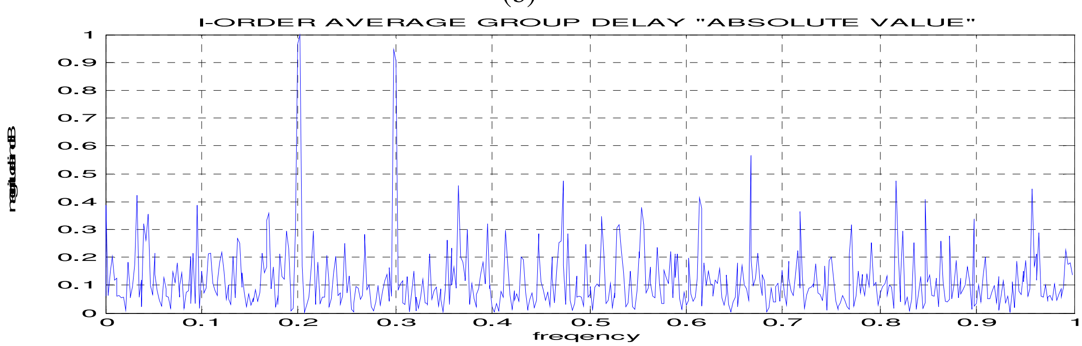
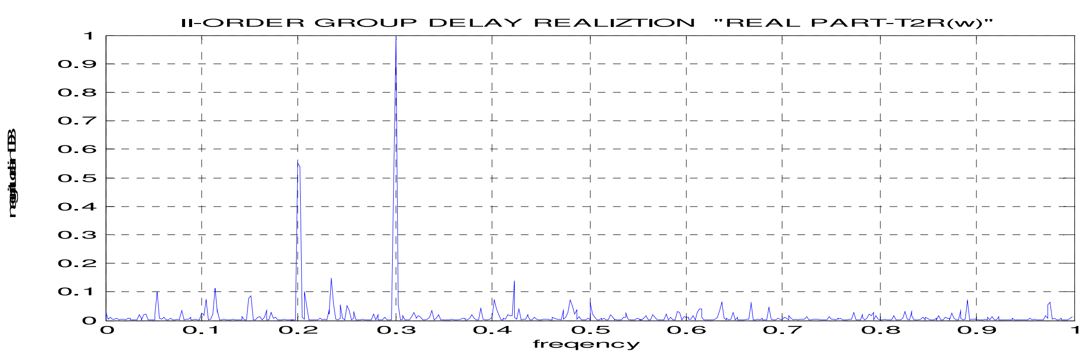


(c)

Fig.4 Estimated I-order absolute values of the group delay function in noise (N=512, SNR=-15dB) (a) Single realizations (clean signal). (b) 50 overlaid realizations. (c) Average realizations.



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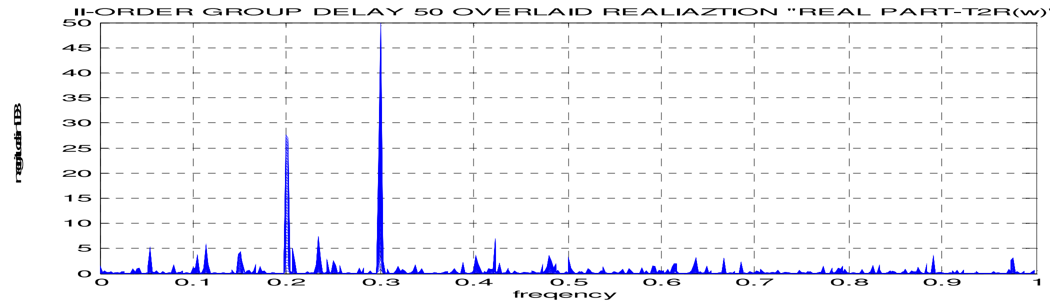

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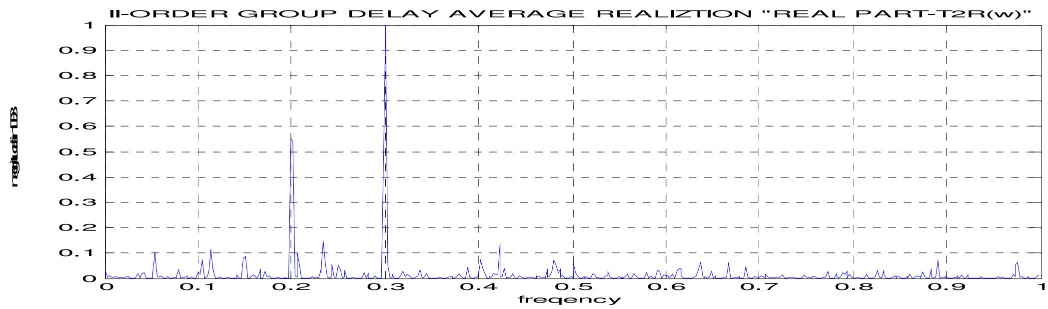
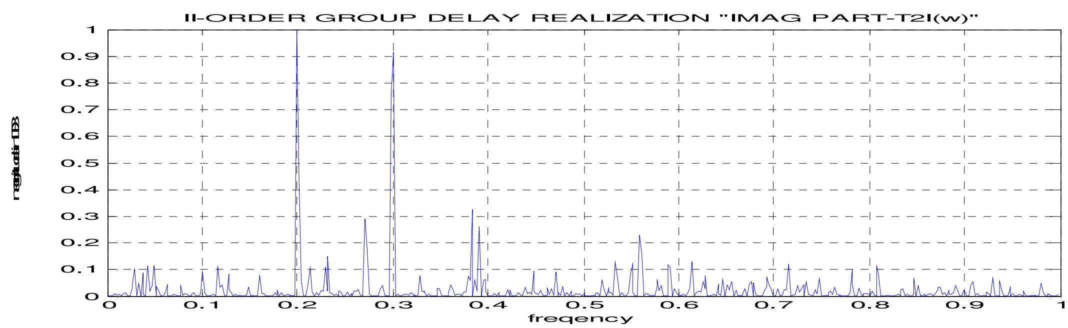


(c)

Fig.5 Estimated II-order real part of the group delay function in noise (N=512,SNR=-15dB)
(a) Single realizations (clean signal).(a) 50 overlaid realizations.(c) Average realizations.



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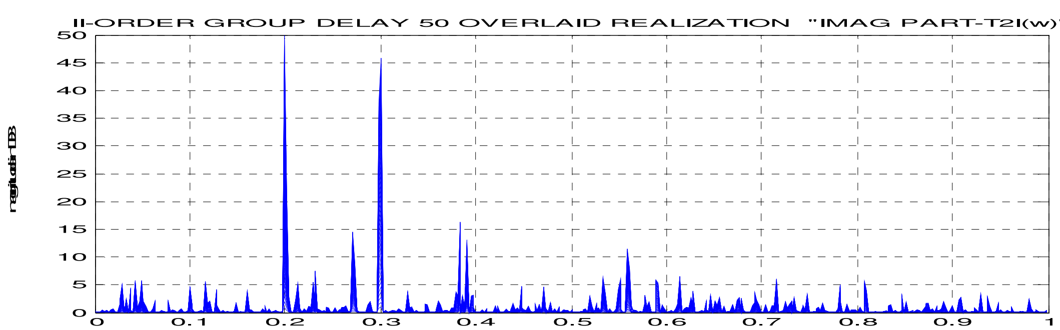

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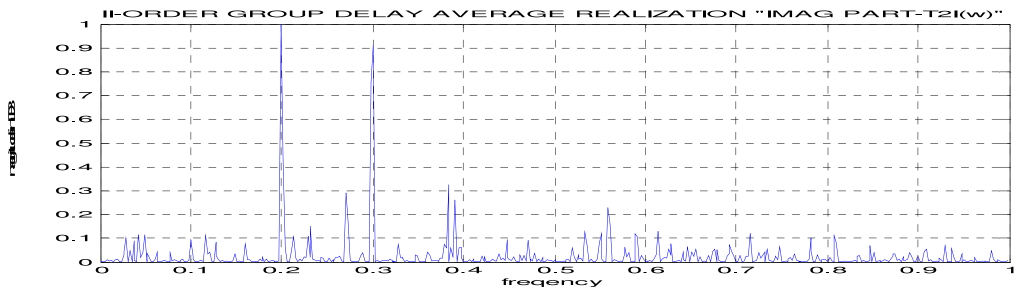
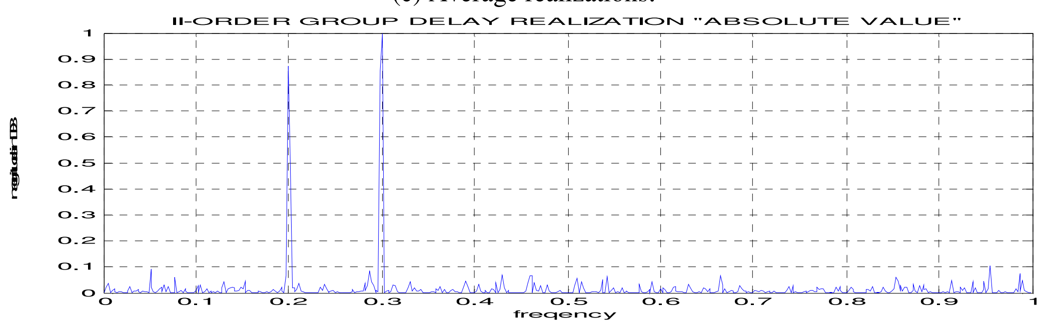


(c)

Fig.6 Estimated II-order imaginary part of the group delay function in noise (N=512, SNR=-15dB) (a) Single realizations (clean signal) (b) 50 overlaid realizations. (c) Average realizations.



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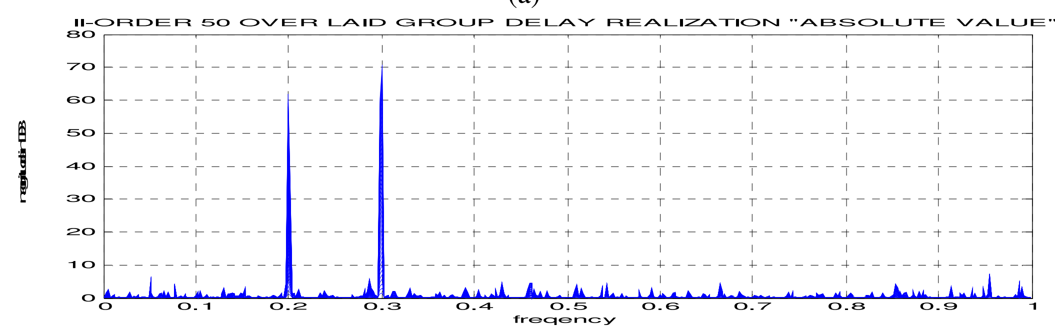

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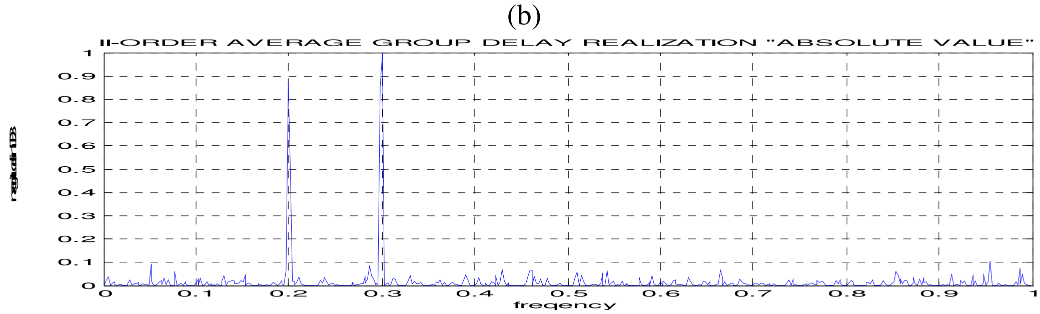
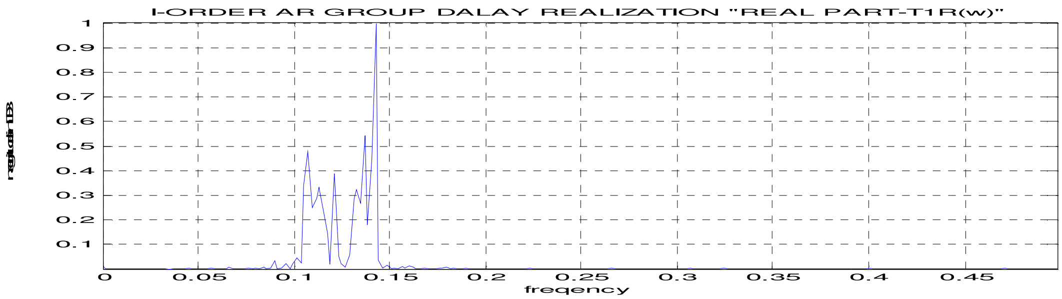


(c)

Fig.7.Estimated II-order absolute values of the group delay function in noise (N=512, SNR=-15dB) (a) Single realizations (clean signal).(b) 50 overlaid realizations. (c)Average realizations.



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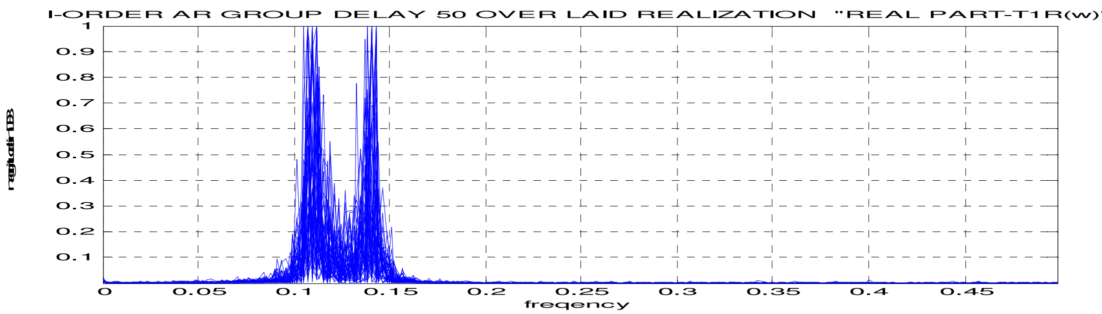

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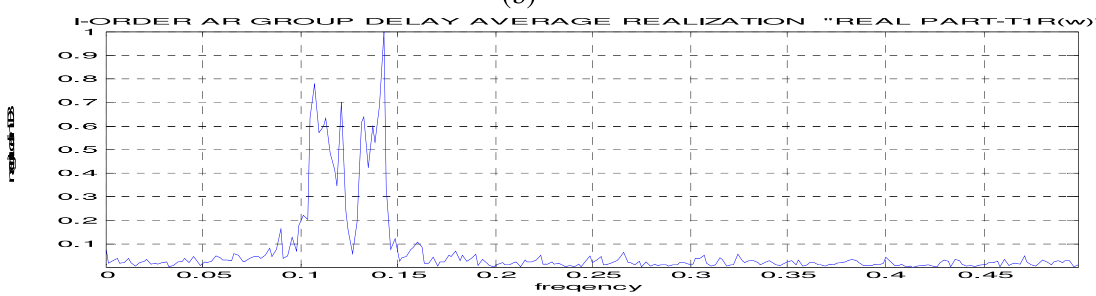

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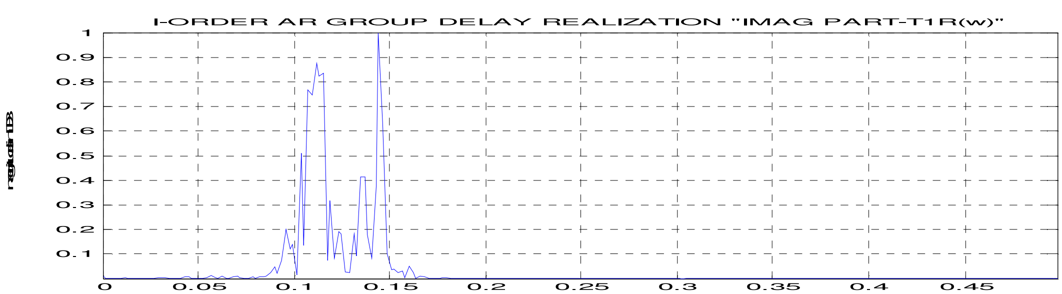
Fig.8 Estimated I-order real part of group delay function for an AR process in noise (N=512,SNR= -15dB) (a)Single realizations(clean signal).(b) 50 overlaid, (c)Average realizations.



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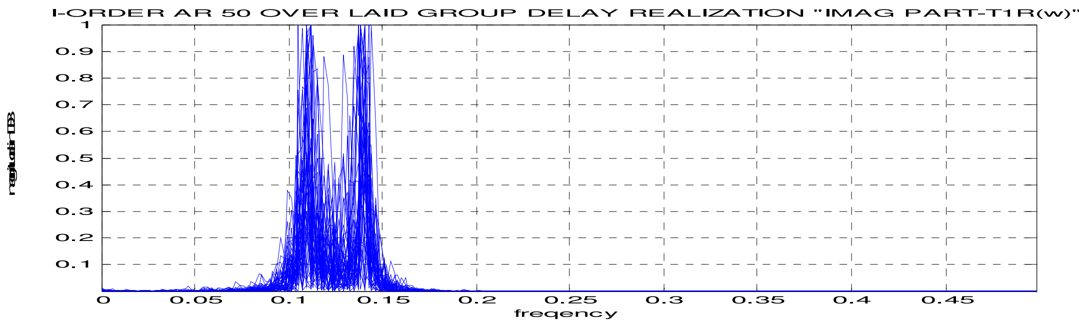

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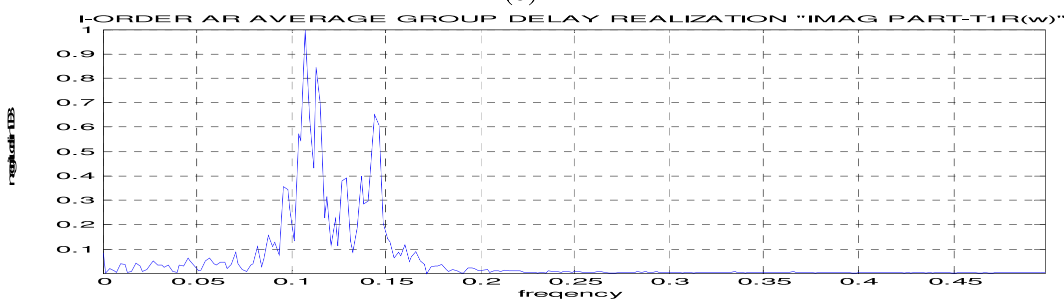
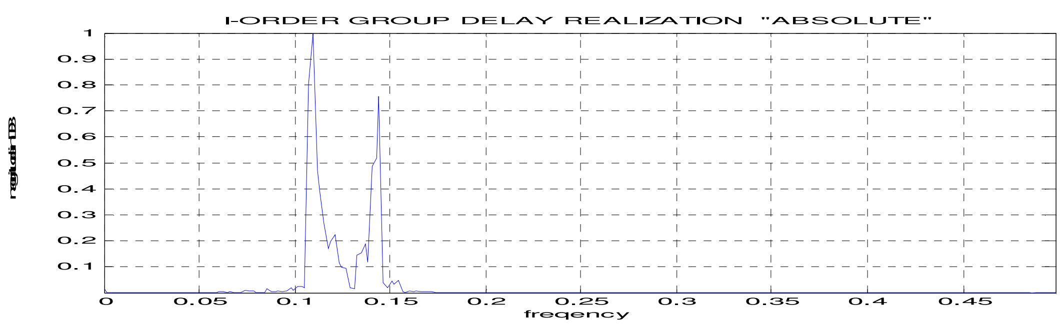


(c)

Fig.9 Estimated I-order Imaginary part of group delay function for an AR process in noise (N=512,SNR=-15dB) (a) Single realizations(clean signal).(b) 50 overlaid realization.
(c)Average realizations.



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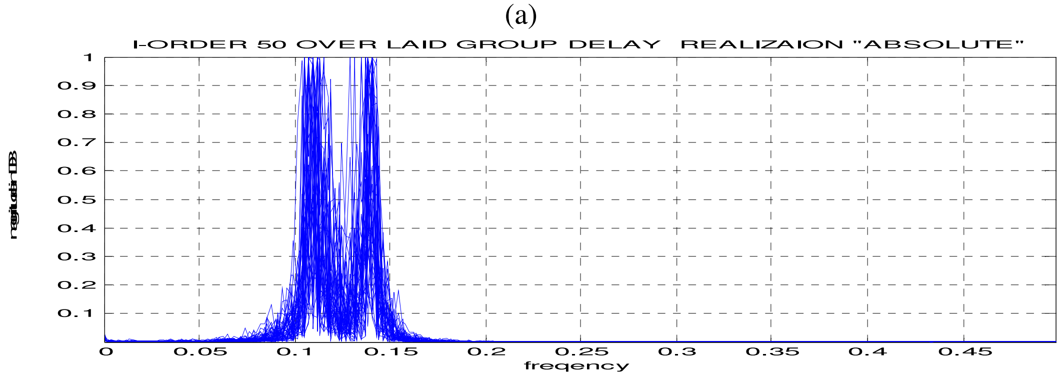

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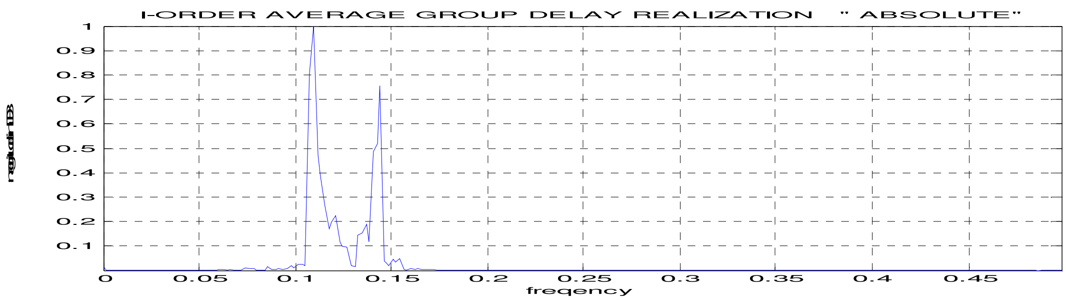

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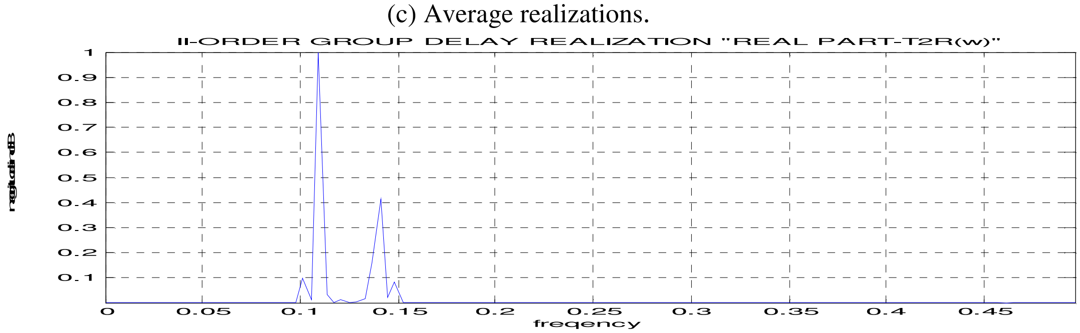
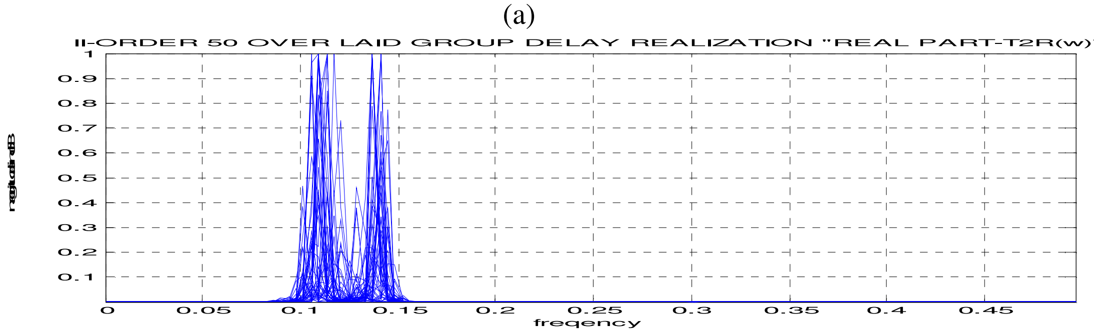
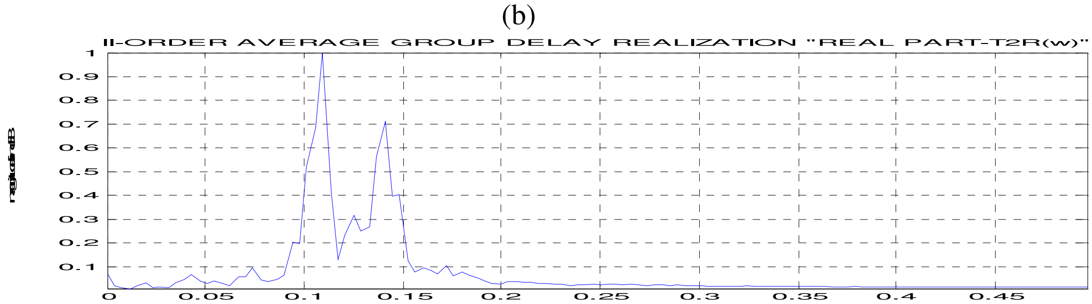
Fig.10 Estimated I-order Absolute values of group delay function for an AR process in noise (N=512,SNR=-15dB).(a)Single realizations(clean signal).(b) 50 overlaid realizations (c) Average realizations.



(a)

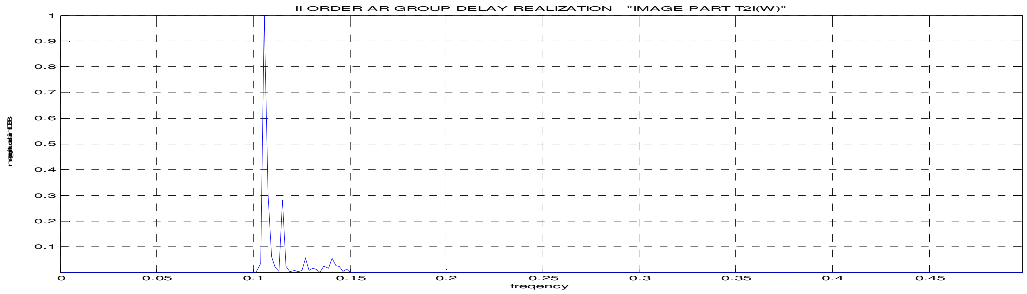


(b)

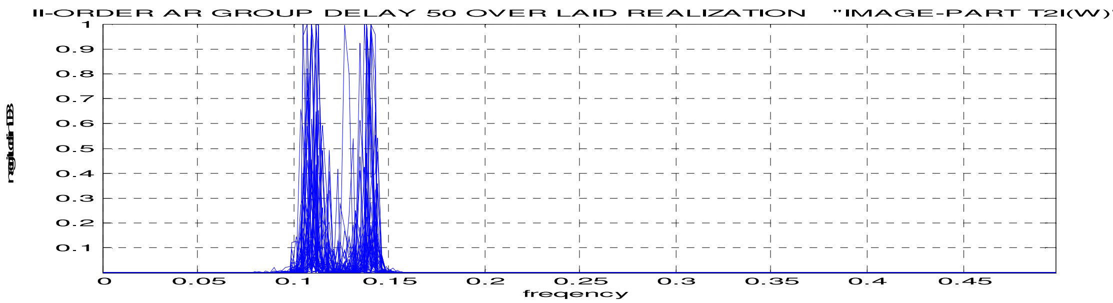


(c)

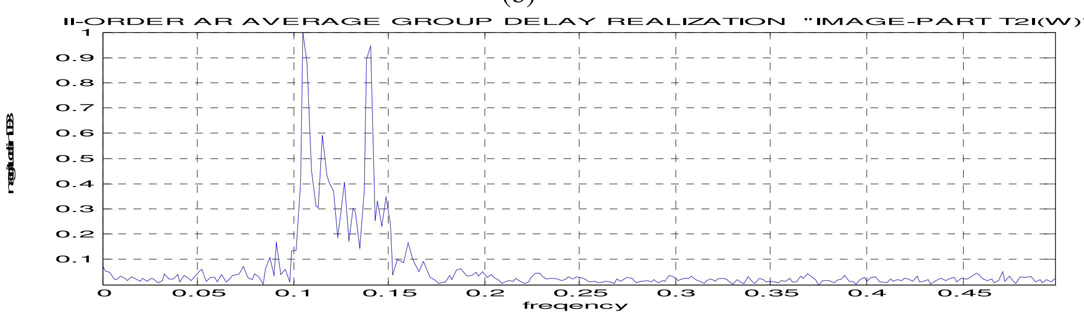
Fig.11 Estimated II-order Real part of group delay function for an AR process in noise (N=512,SNR=-15dB) (a)Single realizations(clean signal).(b) 50 overlaid realizations. (c) Average realizations.



(a)

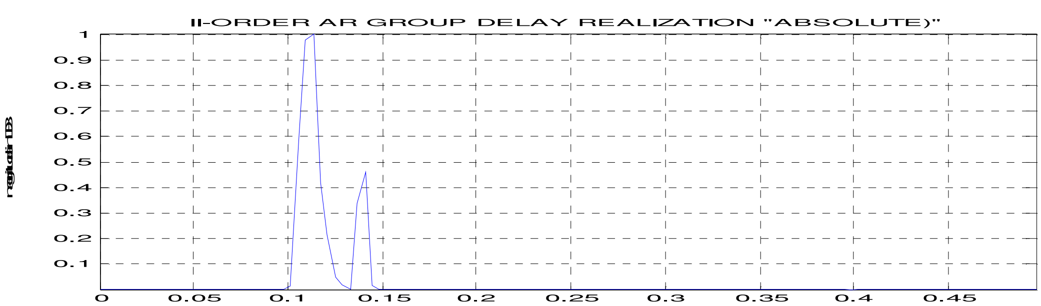


(b)

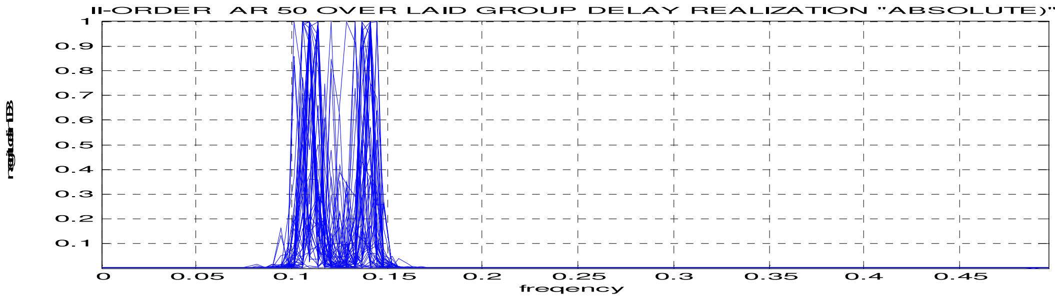


(c)

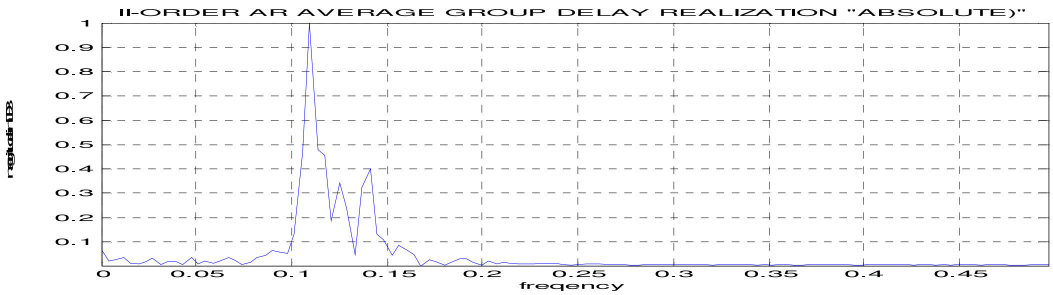
Fig.12 Estimated II-order Imaginary part of group delay function for an AR process in noise (N=512,SNR= -15dB) (a)Single realizations(clean signal).(b) 50 overlaid realization. (c)Average realizations.



(a)



(b)



(c)

Fig .13 Estimated II-order Absolute values of group delay function for an AR process in noise (N=512,SNR= -15bB) (a)Single realizations(clean signal).(b) 50 overlaid realizations (c)Average realizations respectively

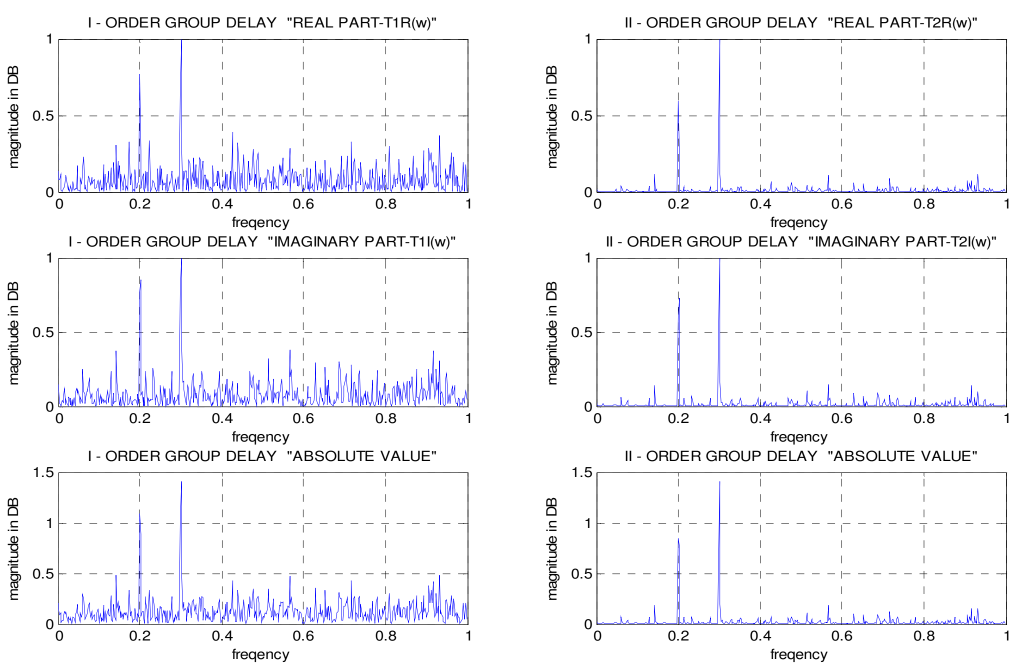


Fig.14.Group delay functions for estimating sinusoidal in noise (N=512, SNR=-15dB) I & II-order real part, imaginary part and absolute values of group delay function realization for comparison

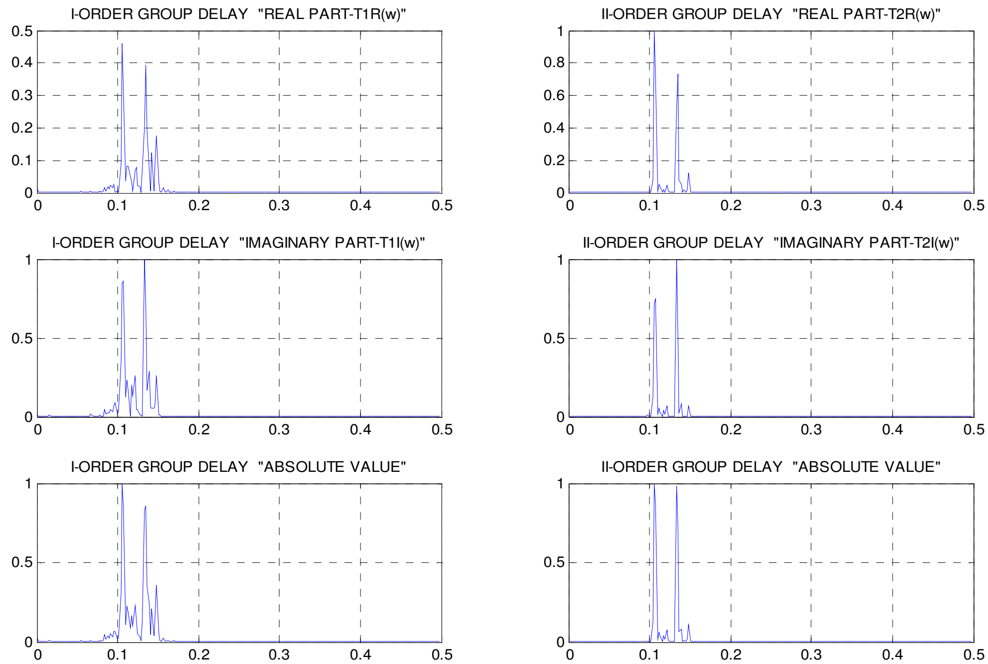


Fig.15.Group delay functions for an AR process in noise (N=512,SNR=-15dB) I & II-order real part , imaginary part and absolute values of group delay function realizations for comparison

6. Conclusion

A new spectral estimation method based on complex I-order and II-order Group Delay has been proposed for the estimation of the signal characteristics. This newly proposed method has been compared with the Group Delay methods proposed by [1].For comparison purpose two examples namely 1) Autoregressive process in noise and 2) Two sinusoidal signals in noise have been considered. The proposed method provides better resolution with reduced variance and also suppresses the spikes generated due to noise in the spectrum compared to first order group delay functions to a great extent. Variance caused by the side lobe leakage due to windows and additive noise is significantly reduced to large extend even in the spectral estimation obtained using a single realization of the observation peak. This method works even for high noise levels (SNR = 0 dB or less).

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References:

[1] B. Yegnanarayana and Hema A. Murthy “Significance of Group DelayFunctions in Spectrum Estimation” IEEE Transactions on signal processing. Vol. 40. NO.9.pp 2281-2289, September 1992.

[2] B. Yegnanarayana, "Formant extraction from linear prediction phase spectra," *J. Acoust. Soc. Amer.,* vol. 63, pp. 1638-1640, May 1978.

[3] Rajesh M.Hegde ,Hema A. Murthy and Venkata Rmana Rao Gadde “ Significance of joint Features Derived from the Modified Group Delay Function in Speech Processing”,EURASIP Journal on Audio, speech and Music Processing vol.2007, Article ID79032,pp.1-12.

[4] .J. Tribolet, “A new phase unwrapping algorithm,” *IEEE Trans.Acoust., Speech, Signal Processing*, vol. ASSP-25, no. 10, pp. 170–177, 1977.

[5] A.V oppenheim and R.W Schafer ‘’ “Digital signal Processing” Englewood cliff,NJ , Prentice –Hall

[6] Abbasian Ali,Marvi Hossien(2009), “The phase spectra based feature for robust speech recognition” ,The annals of “Dunarea De jobs”University of Galati fasclcle III ,Vol.32,No.1,pp 60-65

[7] K. K. Paliwal and L. D. Alsteris, "Usefulness of phase spectrum in human speech perception," in Proc. Eurospeech, Geneva, Switzerland, Sep. 2003.

[8] B.Bozkurt and L.Couvreur,(2005) "On the use of phase information for speech recognition," in Proc. USIPCO, Antalya, Turkey.

[9] D. Zhu and K. K. Paliwal, "Product of power spectrum and group delay function for speech recognition," in Proc. ICASSP, Montreal, Canada, May 2004.

[10] B. Bozkurt, B. Doval, C. D'Alessandro and T. Dutoit, "Improved differential phase spectrum processing for formant tracking," in Proc. ICSLP, Jeju, Korea, Oct 2004.

[11] G.Duncan, B. Yegnanarayana and Hema A. Murthy, "A nonparametric method of formant estimation using group delay spectra," in Proc. ICASSP, pp. 572-575, May 1989.

[12] Yegnanarayana, B., Saikia, D. K., and Krishnan, T. R., “Significance of group delay functions in signal reconstruction from spectral magnitude or phase”, IEEE Trans. on Acoustics Speech and Signal Proc., Vol. 32, no. 3, pp. 610-623, Jun. 1984.

[13] Aruna Bayya and B. Yegnanarayana , "Robust features for speech recognition Systems," in Proc. ICSLP '98, December 1998

[14] G. Farahani, S.M. Ahadi and M.M. Homayounpoor,”Use of spectral peaks in autocorrelation and group delay domains for robust speech recognition” ICASSP 2006,pp: 517-520.

[15] H.A Murthy,K.V.Madhu Murthy and B. Yegnanarayana “Formant extraction from Fourier Transform Phase: in proceedings ICASSP-89 (Glasgo,UK), 1989,pp.484-487.

[16] *Anand Joseph M., Guruprasad S., Yegnanarayana B.”* Extracting Formants from Short Segments of Speech using Group Delay Functions*” INTERSPEECH 2006 – ICSLP, pp:1009-1012*

[17] S.M Kay, Modern Spectral Estimation theory and Application. Englewood cliffs,NJ, Printice Hall.1987

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