PARAMETER ESTIMATION OF CHIRP SIGNAL USING STFT

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Abstract

This paper suggested a technique called short time Fourier transform (STFT) for the parameter estimation of chirp signal in intercept SONAR. STFT is one of the time-frequency method and it is a valuable tool for estimating the parameters like start frequency, end frequency, band width, pulse width and chirp rate of chirp signal. Thus for doing parameter estimation, consider two scenarios: pure chirp signal and chirp signal embedded in noise. Generally the parameter estimation in intercept sonar requires a minimal frequency resolution of 250Hz, but achieved a frequency resolution of 50Hz by using STFT technique which is much higher than the required frequency resolution. Also the maximum tolerable error limit in pulse width estimation is ± 40ms.The simulation results show that in both scenarios, we achieved a lesser error value in pulse width estimation .STFT technique is found to be an efficient tool for the parameter estimation of noisy chirp signal with SNR varies from 0dB to -10dB.

Keywords: *STFT, Chirp Signal, Intercept SONAR, SNR*

I. INTRODUCTION

The conventional signal processing technique based on FFT depends on stationary behavior of the signal, while majority of the signals present in the underwater scenario are time-varying signals. The intercept SONAR does not transmit any signal but it processes the active transmissions from other SONAR'S and estimates the different parameters of intercepted signal. The parameter estimation of intercepted signals is very tedious task, since in intercept sonar there is no prior information regarding the received echo signal. The intercept signal can be chirps or CWM signals. Chirp signals with varying parameters exhibit wide application in active sonar and these chirp signals are produced by the active transmission of other sonar's. During torpedo launch transients will be produced, which also get intercepted by the intercept sonar. The aim is to estimate the parameters of intercept sonar using short time fourier transform technique (STFT),the parameter are namely start frequency, end frequency, pulse width, bandwidth and chirp rate. After estimating the parameters, the resultant information can be used to judge, whether the target is enemy or not.

This paper is organized as follows. The related works is presented in section II. The section III describes the method which is used for parameter estimation of chirp signal. Section IV explains simulation results of proposed method. Section V and section VI deals with conclusion and future scope respectively.

II. RELATED WORKS

Several previous works are depicted in the literature, related to the parameter estimation of chirp signals [1]. Djuric et al. [2] address the problem of parameter estimation of chirp signals embedded in noise and the entire work is based on an assumption that signal to noise ratio is very high. The proposed estimators are very simple, accurate and achieve cramer-Rao bound for SNR higher than 8 dB. Besson et al.[3] suggested two techniques to solve the problem of parameter estimation of signals with randomly time varying amplitude. First method is unstructured non-linear least squares approach (NLS) and second method is a combination of high order ambiguity function (HAF) and NLS. The work in [5] is based on a model of the signal phase as a polynomial and it applies the Kalmann filtering technique for parameter estimation of chirp signals. The work in [4] proposed a fast maximum likelihood algorithm that estimates the frequency and frequency rate of chirp signals embedded in additive gaussian white noise. This paper suggests an approach called short time Fourier transform for parameter estimation of chirp signals in intercept sonar. It is one of the time frequency method used for estimating the parameters of chirp signals like start frequency, end frequency, pulse width, band width and chirp rate.

III. METHODOLOGY

3.1. Short Time Fourier Transform

STFT was introduced by Dennis Gabor [6]. Compared to all existing analysis methods, TFM's like STFT is widely used for analyzing the time varying signals like chirp or transients. STFT technique uses Fourier transform technique to estimate each small section of a signal at a time by windowing the signal. STFT of signal is given by,

$$STFT(t,f) = \int_{-\infty}^{\infty} x(u)h(u-t)e^{-j2\pi f u}du \quad (1)$$

where h(t) is a short time analysis window centered around t=0 and f=0. The multiplication is done by a short window, h(u-t) completely suppresses the signal outside the time point u=t. In STFT technique the chirp signal is divided into shorter segments of fixed size and FFT is applied to each segments.

IV. RESULTS

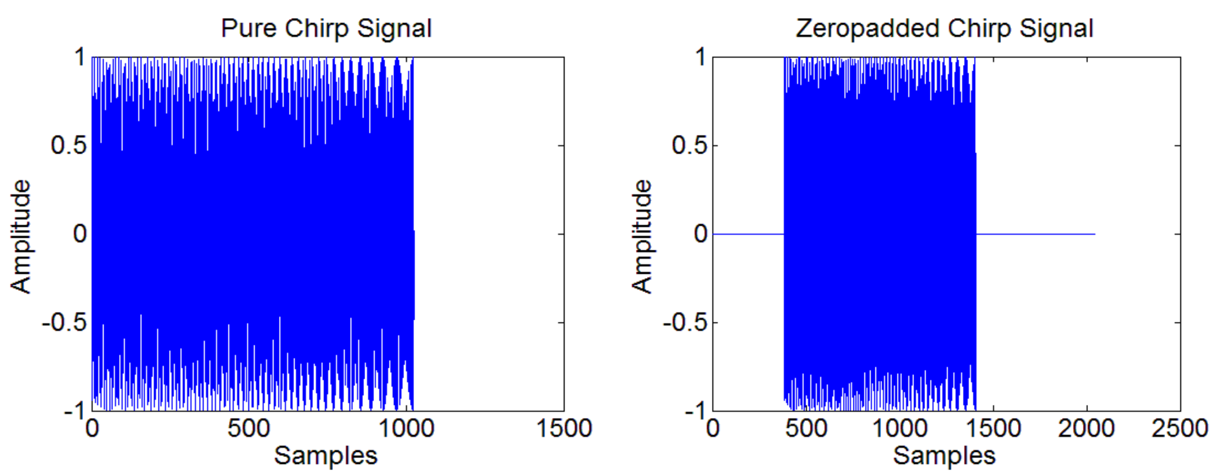
For estimating the parameters of chirp signal in intercept sonar two scenarios are considered:

1. Pure chirp signal

2. Chirp signal embedded in noise with SNR varies from 0dB to -10dB.

4.1. Pure Chirp Signal

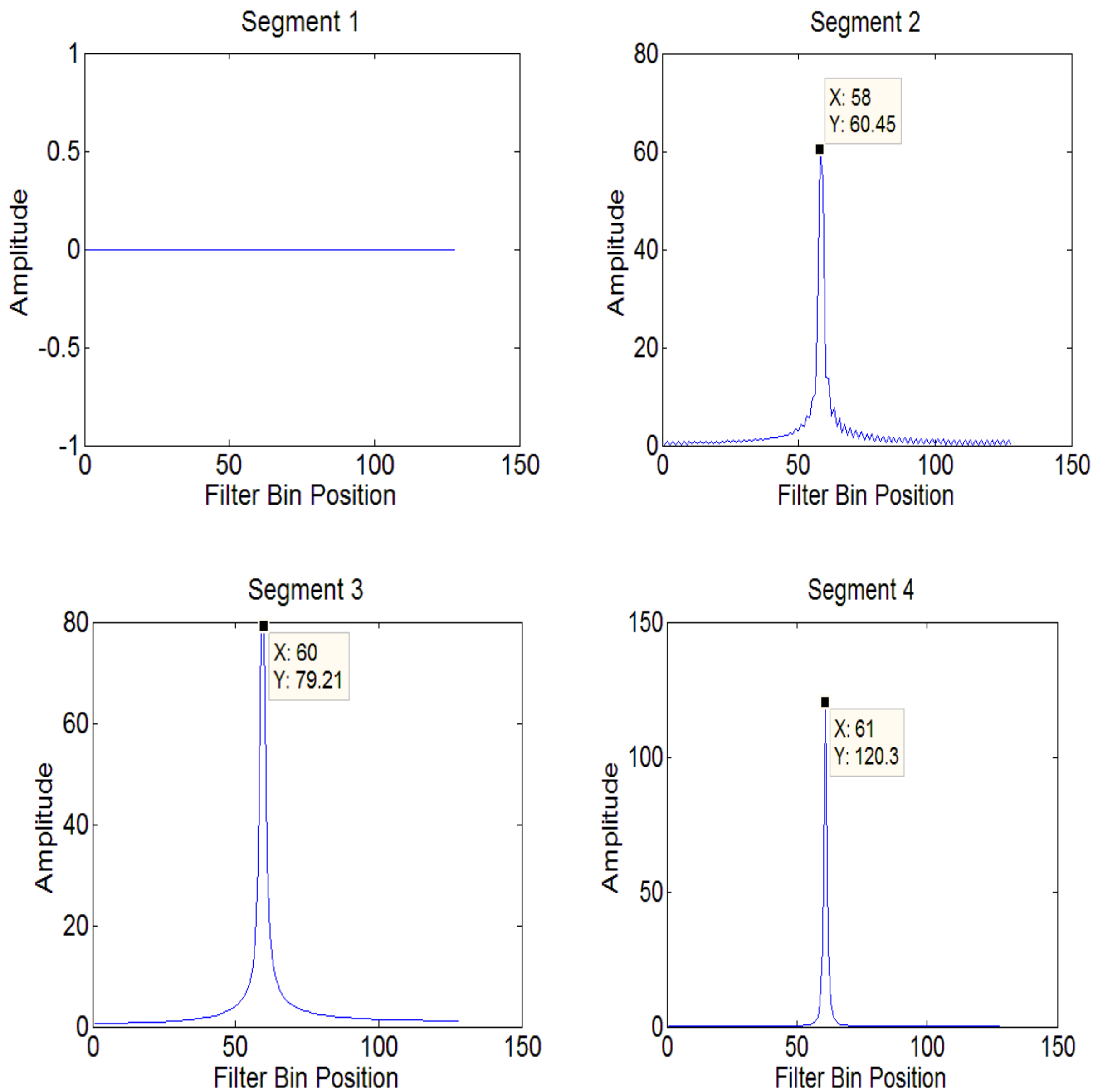
Chirp signal of 3KHZ is generated with pulse duration of 80ms and bandwidth of 300HZ and it contains 1024 samples in the signal. The sampling frequency assumed to be 12.8KHZ. The pure chirp signal is shown in Figure 1a



a) b)

Figure 1. a) Pure Chirp Signal and b) Zero-padded Chirp Signal

The chirp signal is zero-padded to create 2048 samples and STFT is applied to this signal. The zero-padded chirp signal is shown in Figure 1b. In STFT technique a window of fixed size is used ,which divides the signal into shorter segments .On applying a window of size 256 in to the signal , we get 8 segments of data where each segment contain 256 number of samples. The 8 segments of a pure chirp signal is shown in Figure 2. The 1st segment contain full of zeros so there is no output. The presence of a chirp signal is observed on 2nd segment at 57th filter position and presence of chirp signal is ended on 6th segment at 63rd filter position. The remaining 6th & 7th segment contains only zeros.



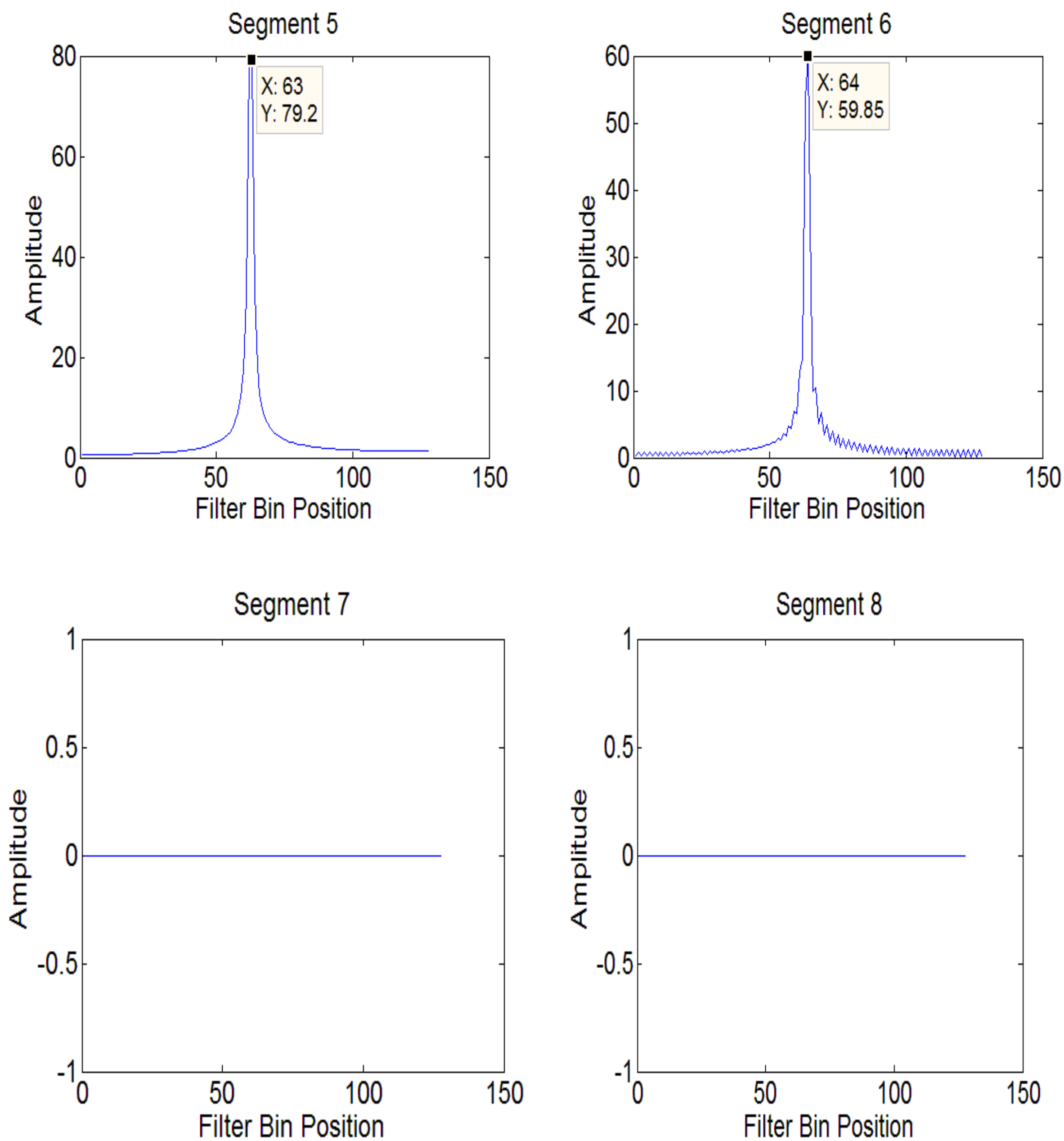


Figure 2: Representation of Output of Eight Segments of Pure Chirp Signal

From Table1, it is clear that, when FFT is applied to each segments of chirp signal ,the filter bin position at which peak amplitude occurs is also changed .The 1st segment contain full of zeros 1st peak position obtained in 2nd segment at 57th filter which corresponds to start frequency of 2850Hz . Last peak position is obtained on 6th segment at 63rd filter which corresponds to 3150Hz frequency. Thus the estimated start and end frequencies are 2850Hz and 3150Hz respectively. The segments output of Pure Chirp Signal is shown in Table 1, point out the non- stationary nature of chirp signal since in each segment, frequency is shifting.

Table 1. Segments Output of Pure Chirp Signal

SEGMENTS	FILTER BIN POSITION	AMPLITUDE
1	--------	-------
2	57	60.45
3	58	79.02
4	60	120.3
5	61	59.2
6	63	59.85
7	---------	-------
8	---------	-------

For pulse width calculation of a chirp signal, normally a threshold value is defined. Based on probability of detection and probability of false alarm, let the threshold value be 60. From the table we can find that only 3 segment were crossing the threshold limit. So pulse width of one segment is given by:

$$Pulse\ Width\ of\ one\ Segment\ = \frac{1}{fs} * Number\ of\ Samples\ in\ one\ Frame \tag{2}$$

where, fs=12.8KHz and number of samples in one segment is 256 since 256 point FFT is used. Using Equation (2) pulse width of one segment is calculated as 20ms; hence pulse width of 3 segment is 60ms .So pulse width of pure chirp signal is estimated with an error of -20ms which is less than the tolerable limit. Band width of chirp signal is calculated by using Eq (3).

$$Band\ Width = End\ Frequency - Start\ Frequency \tag{3}$$

The start frequency obtained is 2850Hz and end frequency is 3150Hz ,so the band width is 300Hz.

Chirp rate of the signal is calculated by:

$$m = \frac{End\ Frequency - Start\ Frequency}{Pulse\ Width} \tag{4}$$

Substitute the parameters like start frequency, end frequency and pulse width in to Eq (4) , chirp rate of the signal can be calculated as 3.75Hz/ms.

Using STFT method, the different parameters of pure chirp signal like start frequency ,end frequency, pulse width, band width and chirp rate were estimated . We estimated the pulse width as 60ms with an error value of -20ms and also achieved a frequency resolution of 50Hz which is much higher than the minimal requirement of intercept sonar.

4.2. Chirp Signal Embedded in Noise

For estimating the parameters of noisy chirp signal, initially a linear chirp with center frequency of 3KHz is generated with sampling frequency of 12.8KHz. The pulse width and bandwidth of the generated chirp signals is 80ms and 300Hz respectively. Then the chirp signal is mixed with random noise to form noisy chirp signal with SNR varying from 0dB to -10dB. Consider a noisy chirp signal as shown in Figure 3, with a SNR of -3dB.

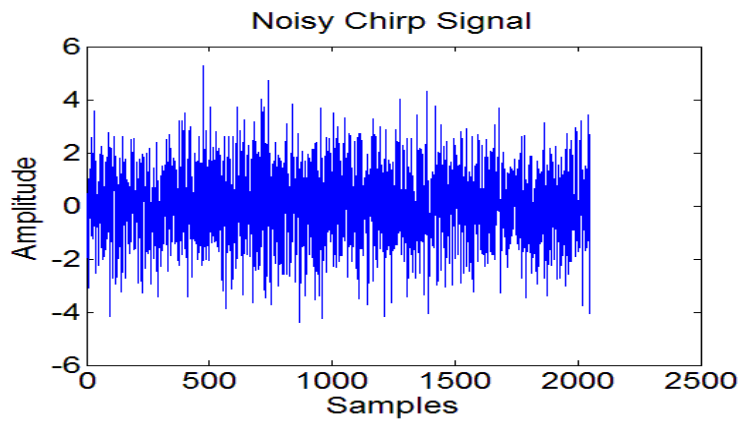
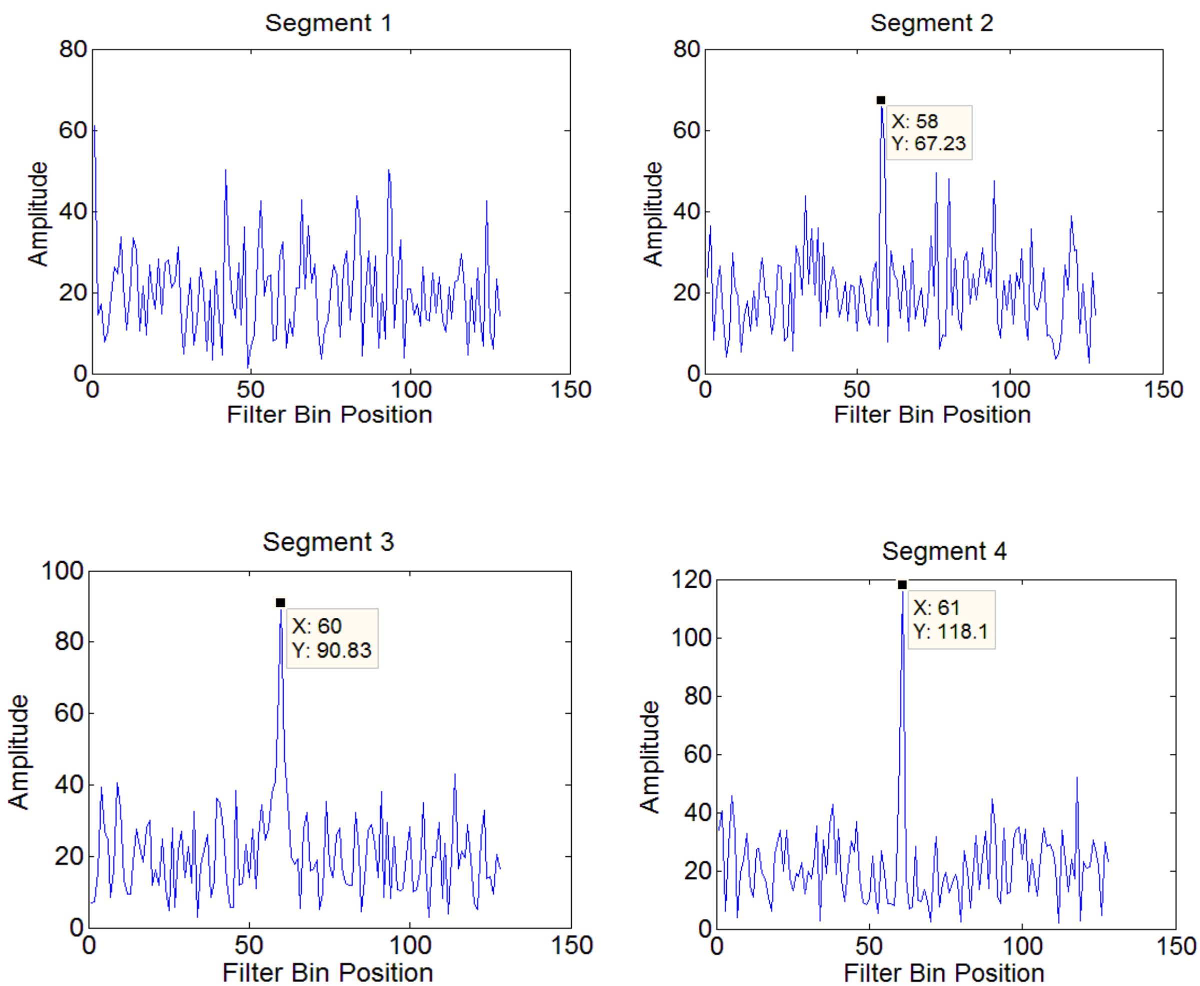


Figure 3. Chirp Signal Containing Noise

Similar to the above case, STFT technique is applied to the noisy chirp signal by using 256 point FFT. Thus we get 8 segments of data with equal number of samples which is depicted in Figure 4.



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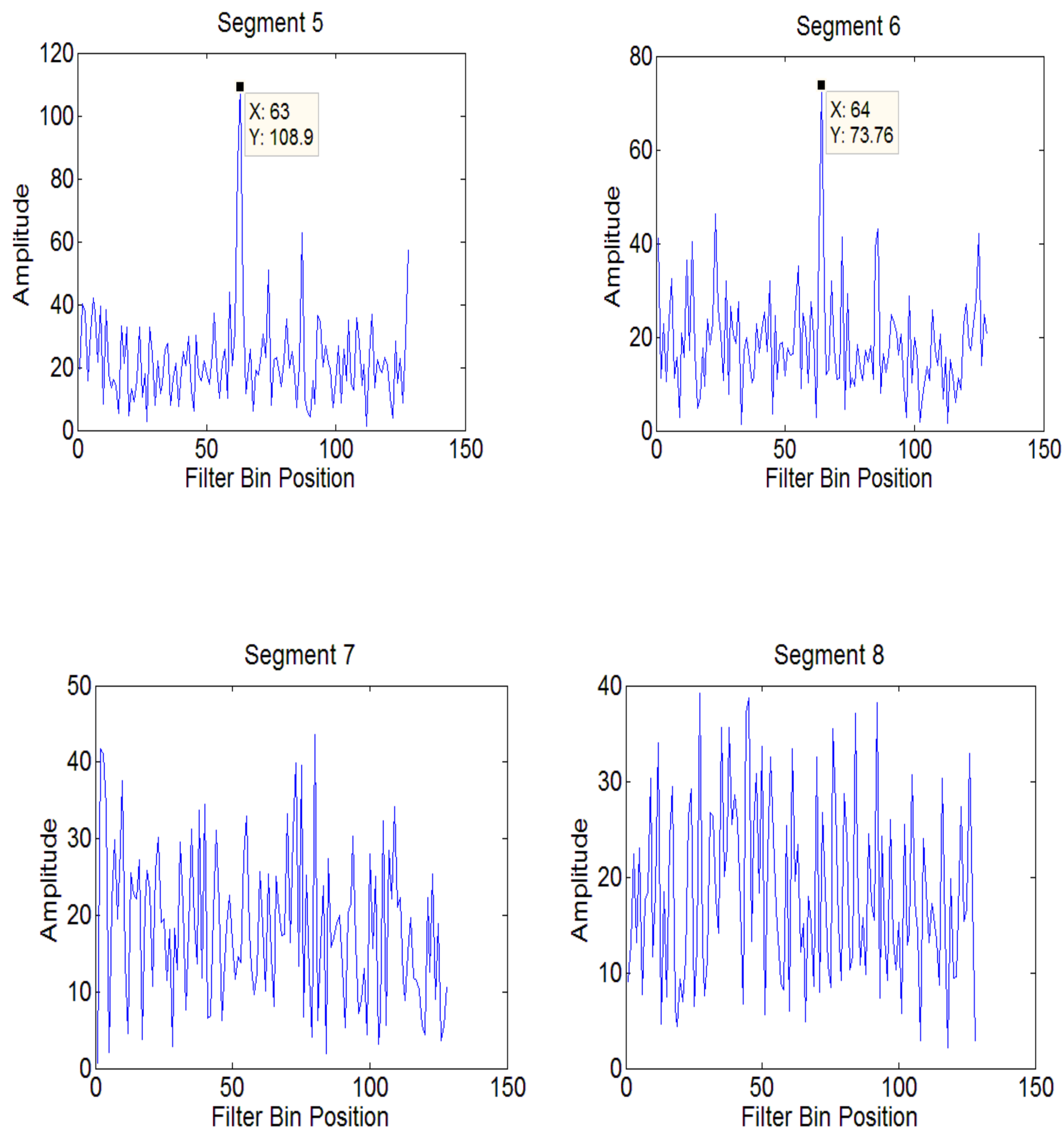

Figure 4: Representation of the Output of Eight Segments of Noisy Chirp Signal

Table 2 shown summarizes the 8-segments output and its corresponding filter bin position at which peak amplitude occurs. It can be see that the 1 st segment contains full of noise .Chirp signal starts at the 2nd segment since it contains the 1st peak amplitude at 57th filter bin position and it is corresponding to frequency of 2850 Hz. The last peak amplitude appears on the 6th segment at 63rd filter which corresponds to frequency of 3150Hz .The 7th and 8th segment contains full of noise. The Start and End frequency of noisy chirp signal is estimated as 2850Hz and 3150Hz

Table 2. Segments Output of Noisy Chirp Signal

SEGMENTS	FILTER BIN POSITION	AMPLITUDE
1	-----------	--------
2	57	67.23
3	58	90.83
4	60	118.1
5	62	108.9
6	63	73.76
7	-----------	--------
8	-----------	--------

For pulse width calculation a threshold value is defined and kept fixed. Let the threshold value be 60. From the table 2, it is clear that five segments were crossing the given threshold limit. Using equation (2), (3) and (4) pulse width of chirp signal is calculated as 100ms, chirp rate is estimated as 3Hz/ms and bandwidth is 300Hz respectively. Hence the different parameters of chirp signal are estimated at SNR= -3dB. Repeat the same procedure for various SNR‘s value up to -10dB and estimate the different parameters of chirp signal like start frequency, end frequency, pulse width, band width and chirp rate.

Table 3. Parameters Estimated for Different Range of SNR's.

Parameter	Pure Chirp	SNR=0dB	SNR= -3dB	SNR = -5dB	SNR = -10dB
Start Frequency(Hz)	2850	2850	2850	2850	2850
End Frequency(Hz)	3150	3150	3150	3150	3100
Band Width (Hz)	300	300	300	300	250
Pulse Width(ms)	60	100	100	60	60
Chirp rate(Hz/ms)	3.75	3	3	5	4.16

Using STFT method, the different parameters of noisy chirp signal is estimated at different SNR's values. At SNR= 0 & -3dB pulse width is estimated as 100ms with an error value of +20ms and at SNR= -5dB & -10dB pulse width is estimated as 60ms with an error value of -20ms. The other parameters like start frequency, end frequency, bandwidth and chirp rate are also calculated with better accuracy.

V. CONCLUSION

This paper suggested STFT technique for parameter estimation of chirp signals in intercept sonar and estimated parameters are start frequency, end frequency, chirp rate, pulse width and band width. The two different scenarios are considered in the simulation works are pure chirp signal and chirp signal embedded in random noise. Generally the parameter estimation in intercept sonar requires a minimum frequency resolution of 250Hz, but we achieved a frequency resolution of 50Hz by using STFT technique which is much higher than the minimal requirement of intercept sonar. Also the maximum tolerable error limit in pulse width estimation is ±40ms. From the simulation results it is clear that in case of pure chirp signal pulse width could estimate with zero error and in case of noise environment pulse width could estimate with ±20ms error value in pulse width estimation .So the STFT technique is proved to be an efficient tool for estimating the parameters of chirp signal in intercept sonar.

VI. FUTURE SCOPE

STFT is found to be a valuable tool for estimating the parameters of chirp signal in both scenarios: pure chirp signal and noisy chirp signal but this method is failed at two cases. First case, STFT is failed in estimating the parameters of noisy chirp signal at lower SNR's. Second case STFT method is failed to differentiate the linear and nonlinear chirp .So in future, we try to develop a new technique which can overcome the shortcomings of STFT technique.

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