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Micro-Doppler signature based target recognition using covariance based S-transform

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Micro-Doppler signature based target recognition using covariance based S-transform

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Abstract: Micro-Doppler signature analysis play an important role for target recognition such as fixed- target, vibrating target, moving human, vehicular motion, etc. Therefore, various signal processing based methods are reported for target recognition. Recently, Short time Fourier transform (STFT), has been applied for target recognition. In this work, we have applied Covariance based S-transform for analysis of fixed target, vibrating target. Also, the performance of Covariance based S-transform method has been compared with STFT.
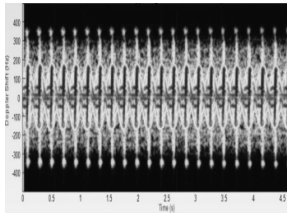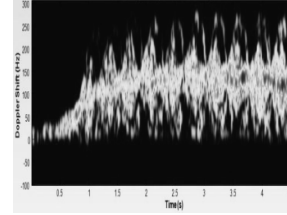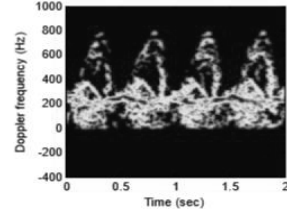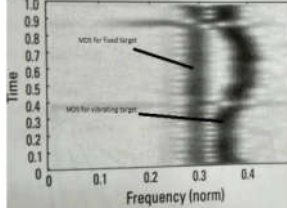
Keywords: Micro-Doppler Signature, spectrogram, STFT, S-Transform

1. Introduction

In this modern era the Radar systems are playing an important role in the applications, where physical contact with target is not possible. These applications are military, navigation, and surveillance. Radar systems are used to get micro-Doppler signatures from the signal, which has been returned from a target. The micro-Doppler signatures are the features associated with the behavior of the target [1]. These systems send electromagnetic waves to the target, which interact with the target and returned back to the system. The behavior of the target has been identified via processing of the received signal. For the processing of the received signal, various methods have been reported in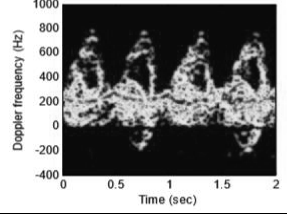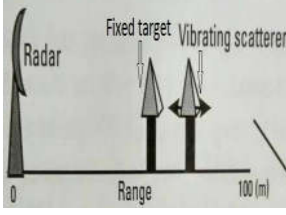 the literature [1], [2]. But, this study is only focused on the time-frequency analysis based methods to identify the behavior based on the micro-Doppler signature of the target. As it is known that the time-frequency analysis techniques provides the information about the signal with respect to the time and frequency simultaneously. Some of the micro-Doppler signatures of the targets have been tabulated [1], [2], [3] & [5] in Table 1.

Table 1. Micro-Doppler Signatures of Various Targets

S.No.	Target	Micro-Doppler Signature
1.		
2.		
3.		
4.		
5.		

In this paper, covariance based Stockwell transform has been proposed for the analysis of micro-Doppler signature of the targets. Also, its performance has been compared with Short Time Fourier Transform (STFT) [7]. The STFT based method is quite common technique to extract the signatures. On the basis of feature of the STFT based spectrogram, the signature of the different activities can be classified very easily [3]. Rest of the paper has been organized in the following sections: Section 2, describes the basic concept and proposed methodology for micro-Doppler signature detection. Results

have been explained using the theoretically simulated signals in Section 3. Finally the conclusion and future directions have been presented in Section 4.

2. Material and Methodology

2.1. Micro-Doppler Target Signatures

Micro-Doppler signatures play a big role to know about the target without any physical contact and these are basically the features of the object or target. The received Doppler-shifted signal from a vibrating target is given in equation (1):

$$S_r(t) = A\left[e^{-(j2\pi f_0 t + \varphi(t))}\right] \qquad (1)$$

where, f_0 is the center frequency of the transmitted signal, A is the amplitude of the received signal, and $\varphi(t)$ is the phase information changes due to the vibrating scattered target. The time-varying phase of a vibrating scattered target is often modeled as in equation (2):

$$\varphi(t) = \beta\sin(2\pi f_v t) \qquad (2)$$

where, $\beta = \frac{4\pi Dv}{\lambda}$, λ is the wavelength and D_v is the amplitude of the vibrations of the transmitted signal. Therefore, equation (1) becomes:

$$S_r(t) = Ae^{-[j2\pi f_0 t + \beta sin\,(2\pi f_v t)]} \qquad (3)$$

The Doppler frequency due to the vibrations of the scattered targets is often represented as [4]:

$$f_D = \frac{1}{2\pi}\frac{d\varphi(t)}{dt} = \frac{4\pi D_v f_v}{\lambda}\cos\,(2\pi f_v t) \qquad (4)$$

From the equation (4), it has been noted that the micro-Doppler signature due to vibrating scattered may be a sinusoidal function of time at the vibrating frequency f_v.

2.2. Covariance based S-transform

The covariance based s-transform has been defined as [9]:

$$S(\tau, f, n, \beta) = \int_{-\infty}^{\infty} h(t)\frac{|f|}{\beta(f)\sqrt{2\pi}}e^{\frac{-(\tau-t)^2 f^2}{\beta(f)^2}}\exp^{-j2\pi ft}dt \qquad (5)$$

Where $\beta(f) = n * \gamma * f$ and $\sigma = n * \gamma$. For this study, we have selected f is the frequency, γ is the covariance, and σ is the standard deviation. The value of $n = 5$ has been selected for the study.

2.3. Proposed algorithm

For the detection of the micro-Doppler signatures from the received signal, covariance based s-transform based algorithm has been shown in Fig.1 and explained below in stepwise manner:

(i)   Firstly the signal has been transmitted from the radar sensor and is received back to the receiver of the Radar sensor.

(ii)   Then, covariance based s-transform has been applied to plot the time-frequency representation or spectrograms of the received signal.

(iii)   And then spectrograms of the detected and existing micro-Doppler signatures have been compared. If both are matched then target is detected else target is not detected.
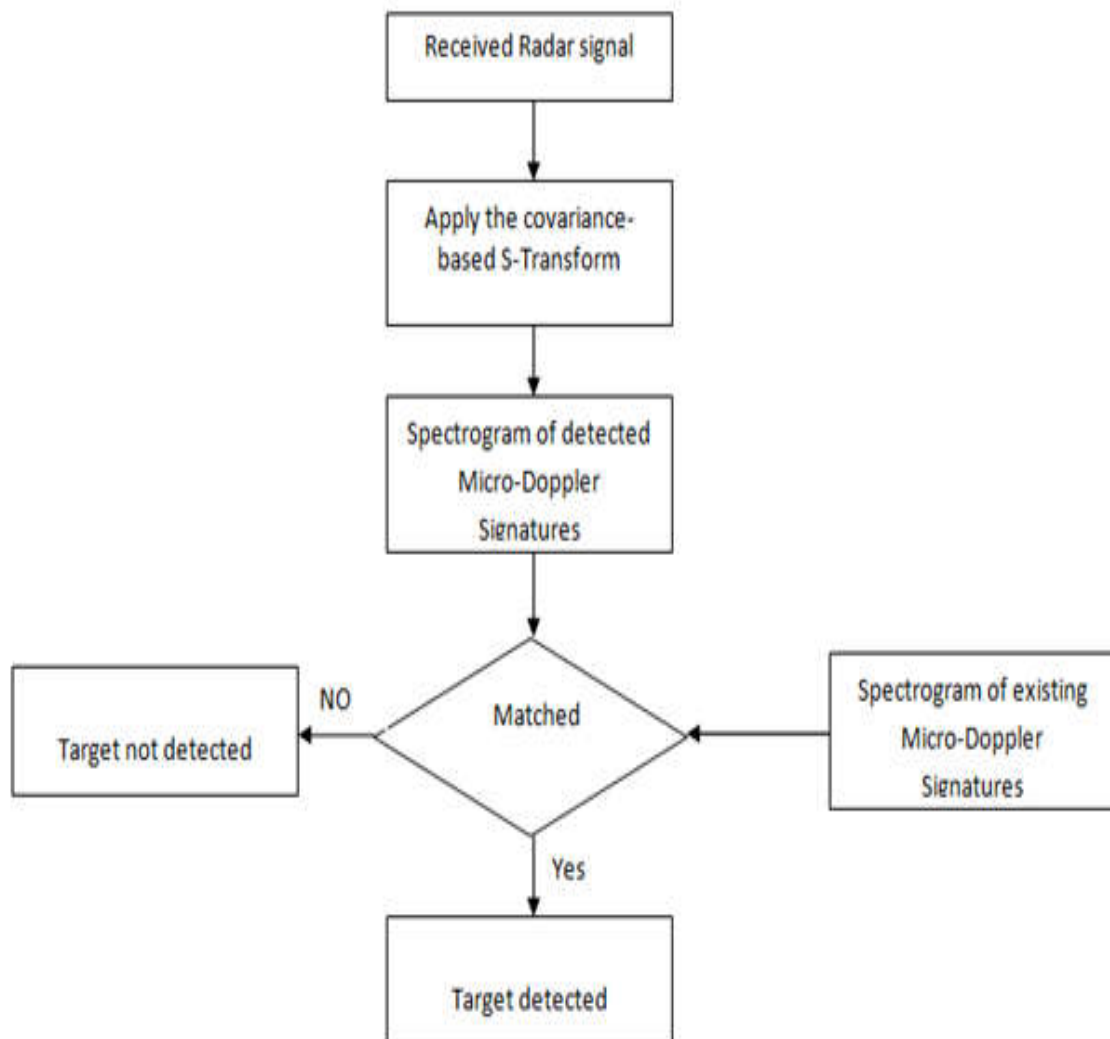
Fig.1 Flow graph of proposed algorithm

3. Experimental Results

In this paper, the proposed algorithm has been tested on the target without and with vibrations. For experiment, radar returned signal has been modeled using equation (3) to analyze the fixed target with and without vibrations. The parameters have been selected for the equation (3) are λ=3cm, $f_v = 10$ Hz , $D_v = 0.1$ cm, and $f_D(t) = 0.66$Hz.

3.1. Fixed Target without vibration

In Fig 2, we have selected the signal for fixed target without vibration i.e $f_v = 0$, λ=0 cm, and center frequency $f_0 = 40$ Hz
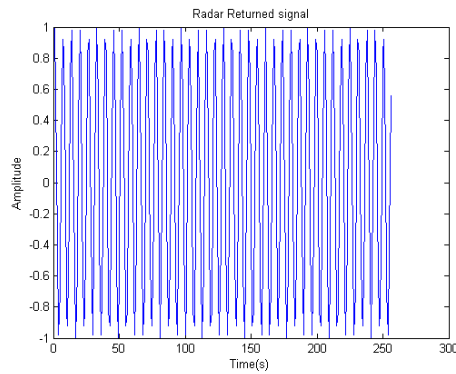

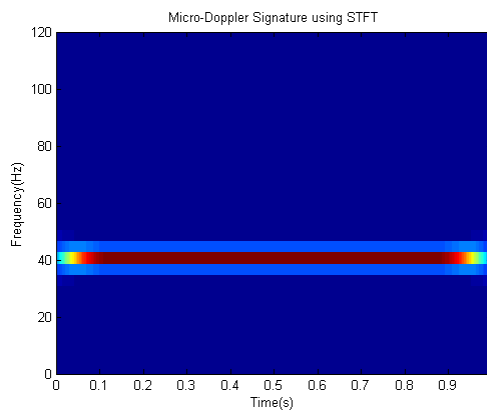**Fig 2.** Radar returned signal of a fixed target without vibration

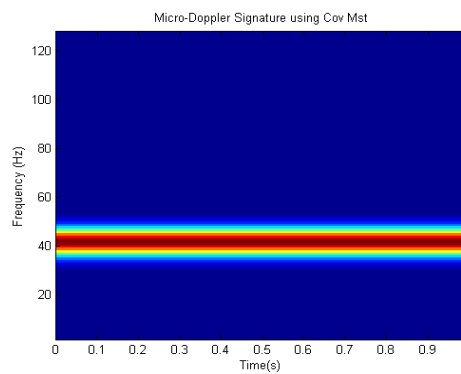**Fig.3** Spectrogram of the signal with fixed target without vibration using STFT

Fig.4 Spectrogram of the signal with fixed target without vibration using Covariance based S-transform

3.2 Fixed Target with vibration

Received signal from the target with vibrations has been generated using equation (3) with parameters $f_v = 10$ Hz A=1, D_v=0.1 cm, λ=3cm, $f_0 = 40$ Hz and it has been shown in Fig.5.

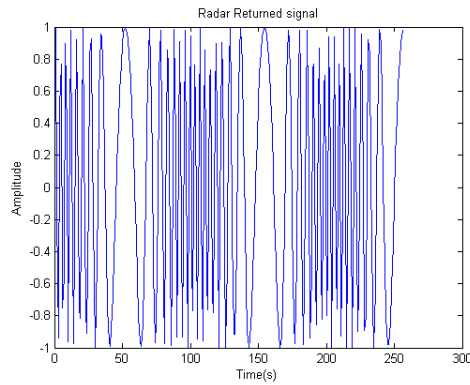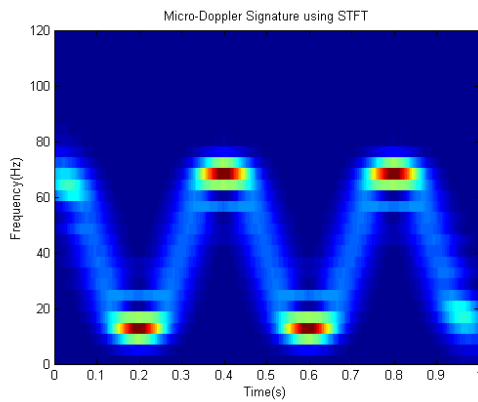**Fig.5** Radar returned signal of a fixed target with vibration

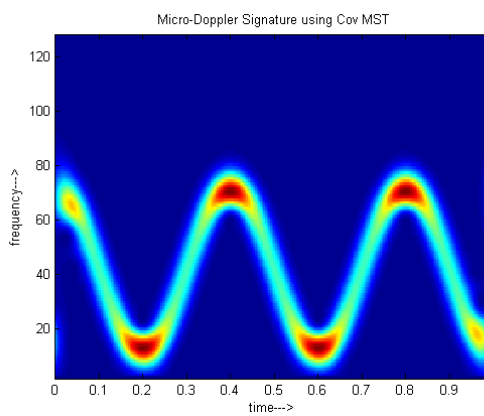**Fig.6** Spectrogram of the signal with fixed target with vibration using STFT

Fig.7 Spectrogram of the signal with fixed target with vibration using Covariance based S-transform

We have plotted the time-frequency plot or spectrogram using STFT and covariance based modified S-transform in Fig.3, Fig.4, Fig.6, and Fig.7. And it has been found that the time-frequency resolution of covariance based s-transform is almost same as STFT for the fixed target. Whereas we have plotted the time-frequency plot for the fixed target with vibrations, and then we found that the time-frequency resolution of covariance based s-transform is better as compared to the STFT for fixed target with vibration.

4. Conclusion and Future work

In this paper, Micro-Doppler Signatures have studied using Short time Fourier transform and covariance based S-transform. And from the results it has been concluded that the spectrogram of covariance based S-transform has good resolution as compared to the STFT based spectrogram. Therefore, good resolution spectrogram can enhance the detection of the micro-Doppler signatures. In future, this work can be extended to include the machine learning for the detection of activities of humans as well as others.

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