Journal of Computing and Communication Vol.1 , No.2 , PP. 80-84 , 2022

A new model of Adaptive Radar Signal Processor based on a time-frequency approach

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ARTICLE DATA

Article history:
Received 10 Jan 2022
Revised 25 June 2022
Accepted 08 August 2022
Available online

Keywords:
***RSP** (Radar Signal Processor)*
***F.T.** (Fourier Transform)*
***FFFT** (Fast Fourier Transform)*
***IFFT** (Inverse Fast Fourier Transform)*
***SNR** (Signal-to-Noise Ratio)*
***BPF** (Band Pass Filter)*

ABSTRACT

This article introduces a novel adaptive technique for improving radar performance in jamming environments. While there are infinite ways to describe a signal, the most fundamental and crucial variables in nature are time and frequency. While the time domain function describes how the amplitude of the signal changes over time, the frequency domain function describes how frequently these changes occur. The Fourier Transform (F.T.) serves as a link between time and frequency. Significant use of the time-frequency transform is detecting and extracting a radar signal jammed by noise. This novel technique for time-frequency processing with a nonlinear threshold level is demonstrated using a chirp radar pulse embedded in noise.

1. Introduction

Typically, radar transient emissions are transitory in time and wide-band in frequency. Due to the difficulty of handling transient signals using classical approaches (such as the Fourier Transform), time-frequency or time-scale analysis [1-4] is better suitable for retaining the high-frequency components of the information provided by transient signals. Compared to the F.T., the time-frequency transform of a transient signal may be more effective at detecting and localizing quick changes in the signal. The detection and extraction of unknown radar signals in noise is a critical application of the time-frequency transform. Time and frequency localization via the time-frequency transform enables de-noising, signal identification, and extraction in the time-frequency domain. This article describes a novel technique for improving radar performance under jamming conditions. This novel technique for time-frequency processing with a nonlinear threshold level is demonstrated using a chirp radar pulse embedded in noise. The reconstructed chirp radar pulse is extremely similar to the original [5-8].

Time-frequency analysis's primary concept is to comprehend and characterize scenarios in which a signal's frequency content changes over time. Time and frequency analysis are insufficient since they do not capture the entirety of what occurs. The primary goal of time-frequency analysis is to develop a procedure for creating a time-frequency domain distribution. We want a joint distribution $P(t, f)$ that indicates the fraction of the total energy contained in the signal at the specified time t and frequency f . The term denotes this distribution. The total energy is obtained by adding all energy bits from distinct time-frequency cells [9-12] .

$$\int_{-\infty}^{\infty} P(t, f)dt \quad df = E \tag{1}$$

Without compromising generality, the signal's strength can be rescaled to equal one in each circumstance. When the energy at multiple frequencies is added up for a specific period, the total energy at that period is obtained. However, the amount of energy available at any particular time is determined by $|s(t)|^2$. As a result, we want our distribution to be as efficient as possible.

$$\int_{-\infty}^{\infty} P(t, f) \quad df = |s(t)|^2 . \tag{2}$$

We should arrive at the frequency density if we add all the timepieces for a particular frequency.

$$\int_{-\infty}^{\infty} P(t, f) \quad dt = |s(f)|^2 \tag{3}$$

The Wigner-Ville distribution [2-4] was the first to be introduced and has received substantial research. It possesses certain outstanding characteristics and serves as the template for these techniques. The Wigner-Ville distribution is as follows;

$$W(t,f)=\int_{-\infty}^{\infty} e^{-j2\pi f\tau} s^{*}(t-\frac{1}{2}\tau)s(t+\frac{1}{2}\tau)\ d\tau \qquad (4)$$

Having a straightforward method for generating all potential time-frequency distributions has several significant advantages. This enables one to pick and choose which qualities are desirable. This is a feasible strategy that can be expressed in various ways. The simplest approach is to create distributions directly from [5], [6].

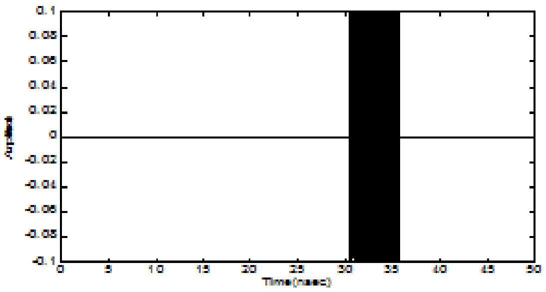
$$P(t,f)=\iiint e^{j2\pi\nu(u-t)} g(\nu,\tau)s^{*}(u-\frac{1}{2}\tau)s(u+\frac{1}{2}\tau)e^{-j2\pi f\tau} d\nu \quad du \quad d\tau \qquad (5)$$

Where the kernel $g(\nu,\tau)$ is an arbitrary function, after selecting a kernel, the distribution is fixed. We consider only kernels that meet these conditions to analyze the class of distributions that fulfil the marginal.

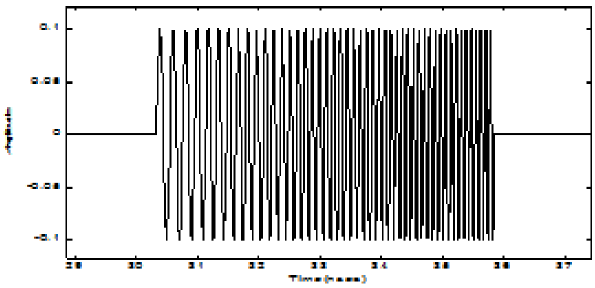
2. PROCESSING BASED ON TIME-FREQUENCY

The Signal-to-Noise Ratio (SNR) of noisy chirp data is approximately (-4.6693) dB. The time domain representations of the chirp radar pulse in clear and noisy environments are given in Figure 1. As illustrated in this Figure, the chirp radar pulse is enveloped in a high noise level.

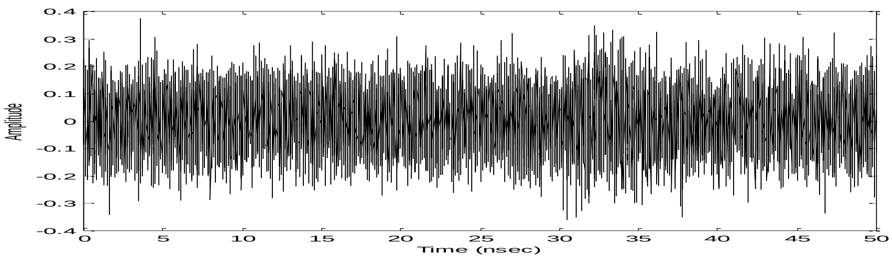
In the time-frequency domain, Figure 2 depicts a Three-dimension representation of the chirp radar pulse enveloped in noise. Additionally, it represents the frequency of occurrences at any given time.



(a) Chirp radar pulse at a clean environment



(b) Zoom at a Chirp radar pulse at a clean environment



(C) Chirp radar pulse enveloped in noise

Figure 1: Representation of the chirp radar pulse in both clear and noisy environment respectively

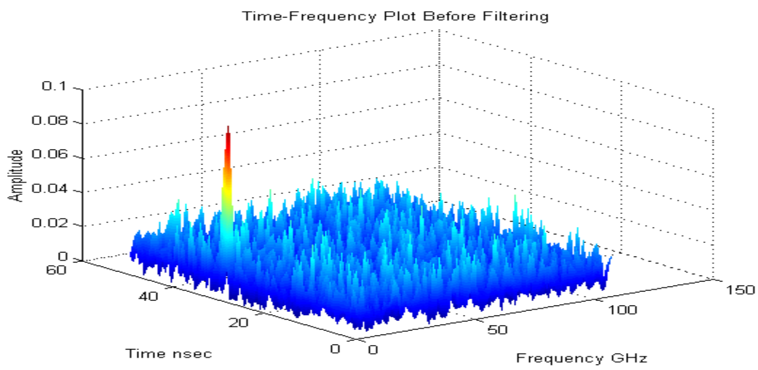


Figure 2: Three-dimension representation of the chirp radar pulse enveloped in noise

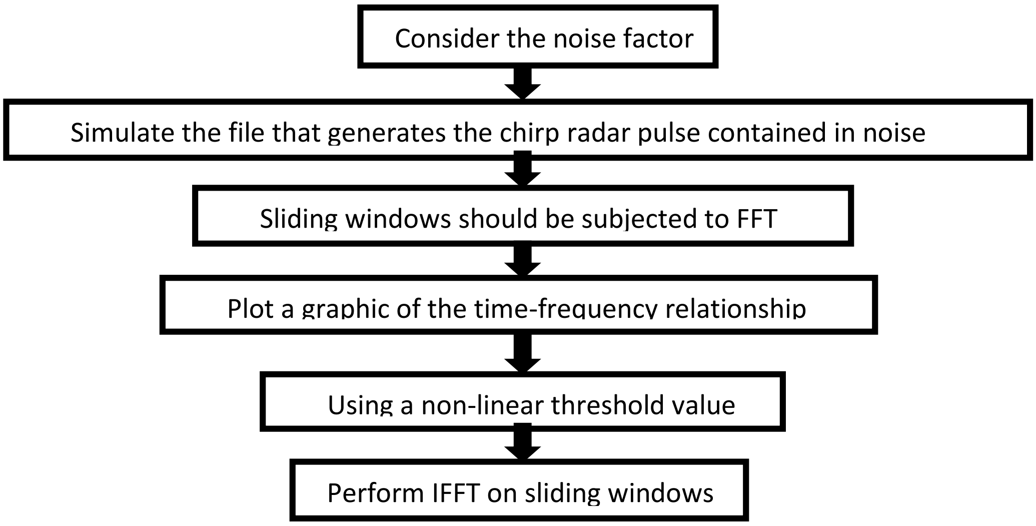


Figure 3: Flow Chart of the proposed adaptive time-frequency processing strategy

This technique slides a time series and applies the Fourier Transform on 128 samples distributed across 85 windows. It employs nonlinear filtering and an Inverse Fourier Transform over all windows to retrieve the chirp radar pulse. Finally, it determines the Signal-to-Noise Ratio. The output of the time-frequency filter decides the signal power. After that, the power of the signal plus the noise is determined using the formula SNR = signal/noise (signal plus noise- signal). Figure 4 illustrates a three-dimensional representation of a recovered chirp radar pulse from noise following the use of a nonlinear threshold

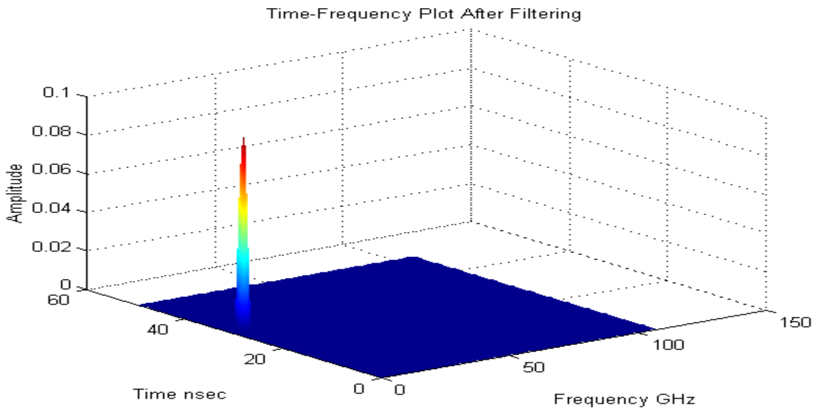
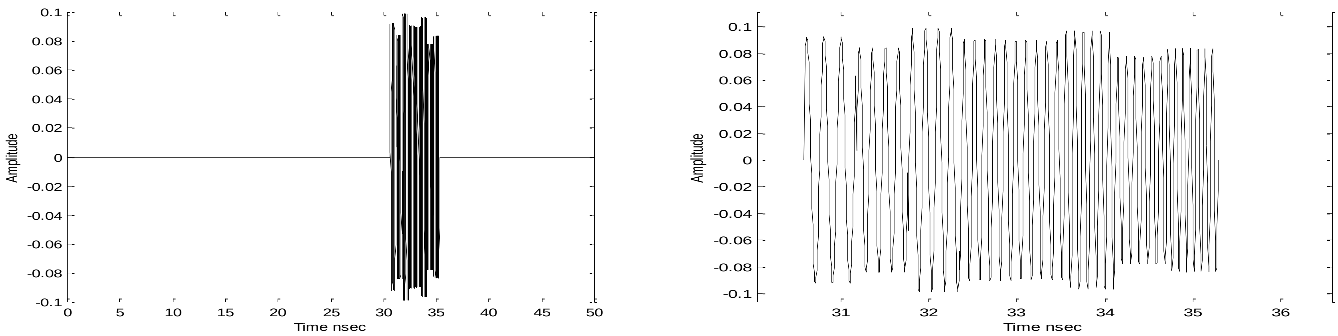
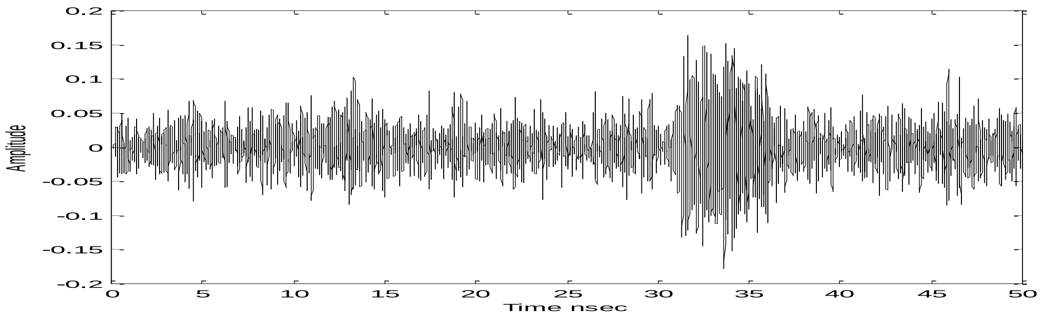


Figure 4: Three dimensions representation of a recovered chirp radar pulse in the time-frequency domain

Figure 5 illustrates the representation of the recovered chirp radar pulse using IFFT for each window. The adaptive time-frequency technique successfully extracts the chirp radar pulse from noise, but the conventional filter fails.



(a) Re ... equency algorithm



(b) Output of the conventional BPF tuned to the chirp radar pulse.

Figure 5: (a) Representation of the recovered chirp radar pulse using adaptive time-frequency algorithm (b) Output of the standard BPF tuned to the chirp radar pulse.

It is extremely instructive to compare the spectrum of the recovered chirp radar pulse generated by the adaptive time-frequency algorithm to the spectrum of the standard BPF as seen in Figure 6.

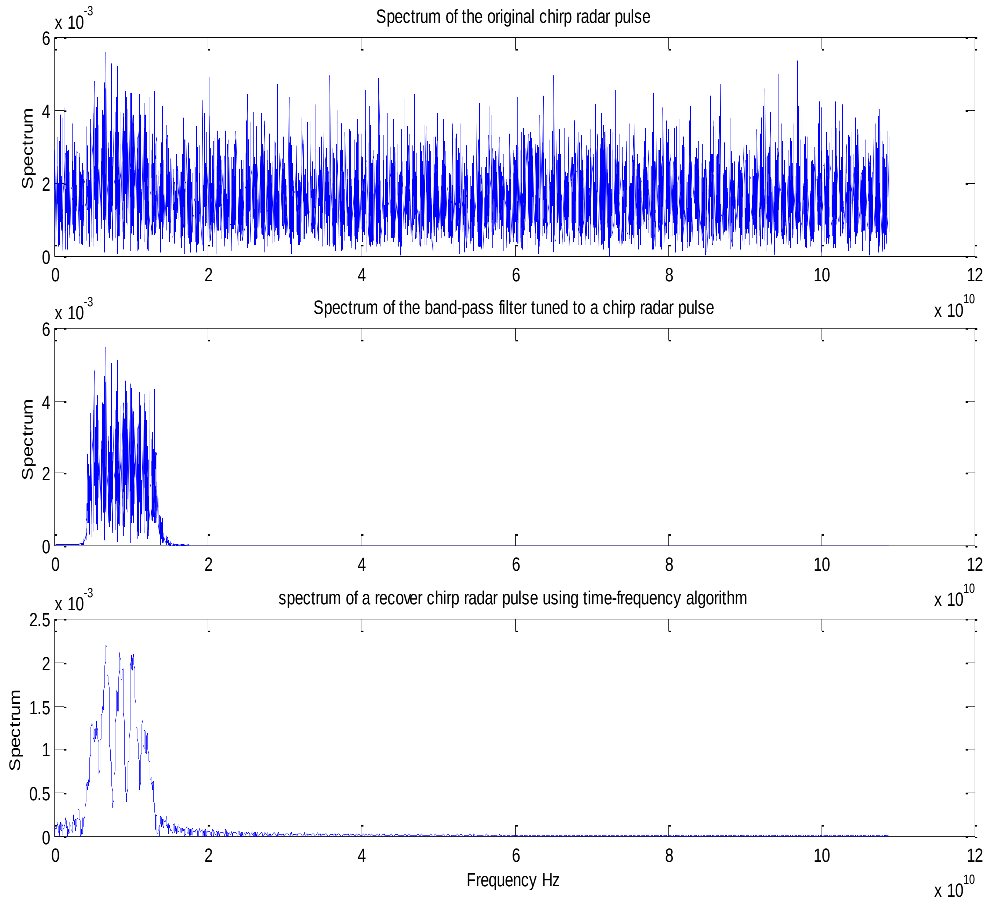


Figure 6: Spectrum of the chirp pulse, the spectrum of the conventional BPF, and spectrum of the recovered chirp pulse using the time-frequency algorithm

3. Conclusion

This paper introduces a new technique to improve radar performance under jamming conditions. This new technique of adaptive time-frequency processing with a nonlinear threshold level is applied to the chirp radar pulse embedded in noise. The analysis aims to detect, extract the signal and recover the radar pulse. The recovered radar pulse has an excellent agreement with the original one.

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