Analysis and Simulation of LFM Signal Feature

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Abstract. Chirp signal is the first study to obtain a pulse and widely used compressed signals. Compared with other pulse pressure signals, a matched filter for the Doppler frequency shift of the echo signal is not sensitive, it is possible to deal with a matched filter having a different Doppler shift signal, which will greatly simplify the signal processing system. In this paper, the main characteristics of the time-domain and frequency chirp signals, fuzzy aspects of introduction and analysis functions, and so lay the theoretical foundation for the study of pulse radar detection algorithm accumulation.

Introduction

In order to solve the contradiction between the role of distance and resolution, in theory under the guidance of the matched filter to produce a pulse compression concept. Many, including the chirp signal, two-phase encoded signal, polyphase codes, linear FM signal and the frequency phase mixed signal pulse compression and other types of signals. A pulse is a chirp signal which was first studied and widely used compressed signals. Compared with other pulse pressure signals, it has the following advantages: The matched filter Doppler frequency shift of the echo signal is not sensitive, it is possible to deal with a matched filter having a different Doppler shift signals, which will greatly simplify the signal processing system; in addition, the generation and processing of these signals compared easily, and technically more mature, and this is the reason it gets widely used. Figure 1 shows a block diagram of a typical chirp radar.

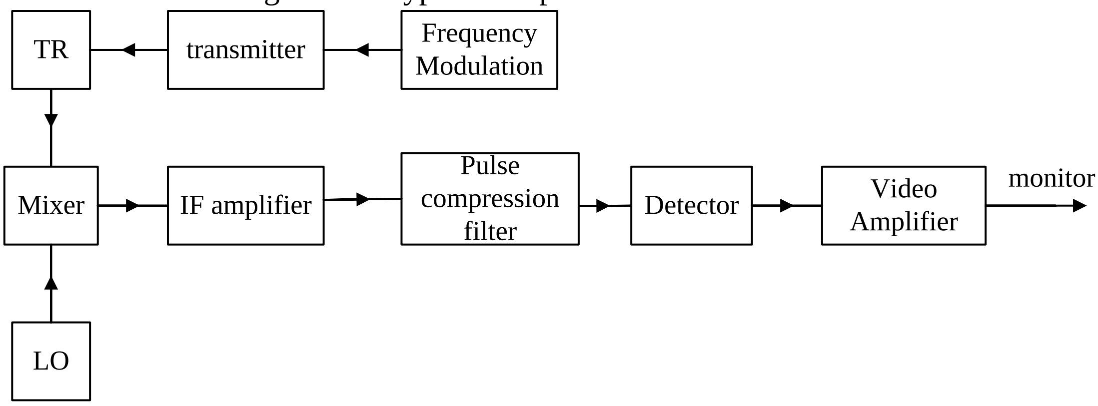


Figure 1. The block diagram of a chirp radar

The spectral characteristics of chirp signals

Expression of chirp signal is:

$$s(t) = \mathrm{rect}\left[\frac{t}{T}\right] \cdot \exp\left[\mathrm{j}2\pi\left(f_0 t + kt^2/2\right)\right] \tag{1}$$

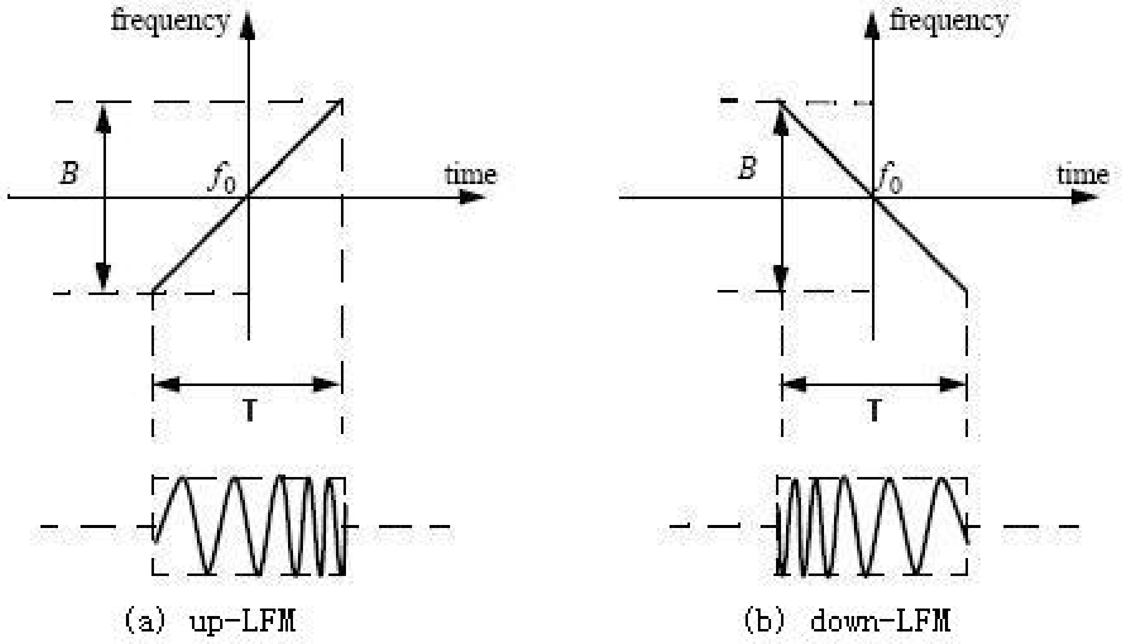
Wherein, T is the pulse duration, f_0 is a carrier frequency, k=B/T is the chirp rate, and B is the signal bandwidth. rect[] rectangular envelope, E is defined as:

$$\mathrm{rect}[t] = \begin{cases} 1 & |t| \le 1/2 \\ 0 & \text{other} \end{cases} \tag{2}$$

Of the formula (1) in the time domain for the differential phase, the instantaneous frequency of the signal:

$$f(t) = f_0 + kt \tag{3}$$

Thus, the frequency Chirp signal is f_0 as the center, increasing linearly with time (or decreasing) relationship. As shown in FIG. 1 is a typical Chirp signal.



Frequency domain version of Chirp signal is:

$$S(f) = \frac{1}{\sqrt{2k}} \exp\left(-j\pi f^2/k\right)\left\{\left[c(U_1)+c(U_2)\right]^2 + j\left[s(U_1)+s(U_2)\right]^2\right\} \tag{4}$$

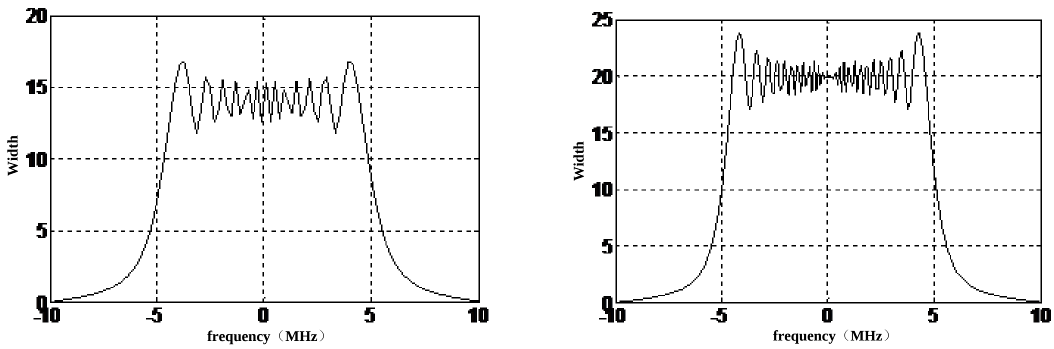
Wherein, c (U) and s (U) for the Fresnel integral:

$$\begin{aligned} c(U) &= \int_0^U \cos\left(\pi x^2/2\right)\mathrm{d}x \\ s(U) &= \int_0^U \sin\left(\pi x^2/2\right)\mathrm{d}x \end{aligned} \tag{5}$$

U_1 and U_2 for the generation of integral variables:

$$\begin{aligned} U_1 &= \sqrt{2K}\left(T/2 - f/k\right) \\ U_2 &= \sqrt{2K}\left(T/2 + f/k\right) \end{aligned} \tag{6}$$

Figure 3 shows the TB=50 and TB=100 of Chirp signal spectrum. As can be seen from the figure, the frequency-domain waveform Chirp signals within the bandwidth exhibits oscillations, and a large value corresponds to TB Fresnel ripple smaller amplitude frequency closer to a rectangle. When TB=100, the energy within the rectangle representing the signal energy of the entire 98% to 99%.



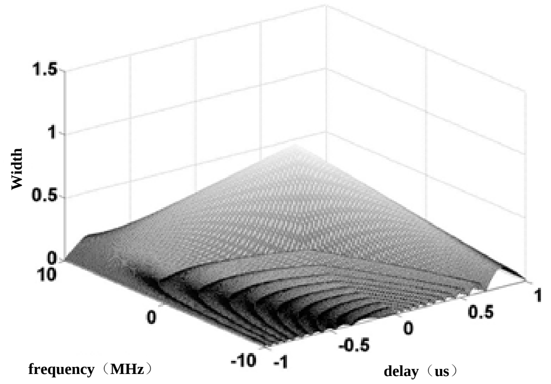
(a) TB=50 (b) TB=100

Figure 3. Different TB value corresponding Chirp signal amplitude-frequency characteristics

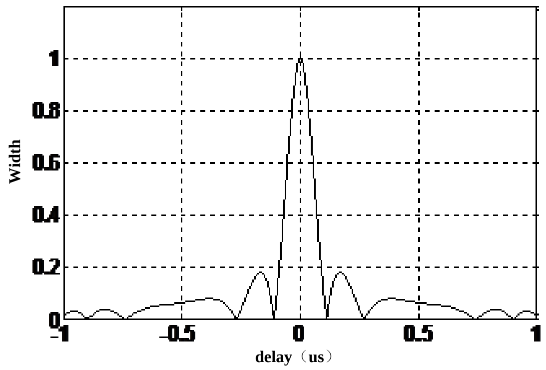
Chirp signal ambiguity function

Chirp signal ambiguity function is:

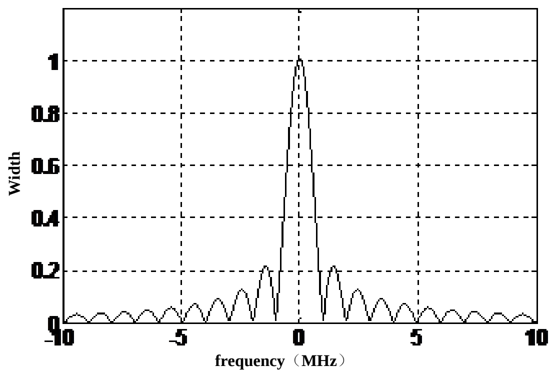
$$\chi(\tau, f_d) = \begin{cases} (T-|\tau|)\mathrm{sinc}\left[\pi(f_d - k\tau)(T-|\tau|)\right] \\ \cdot\exp\left\{ j\pi\left[(f_d - k\tau)(T-\tau) - k\tau^2\right]\right\}, & |\tau| < T \\ 0 & , \quad \text{other} \end{cases} \tag{7}$$



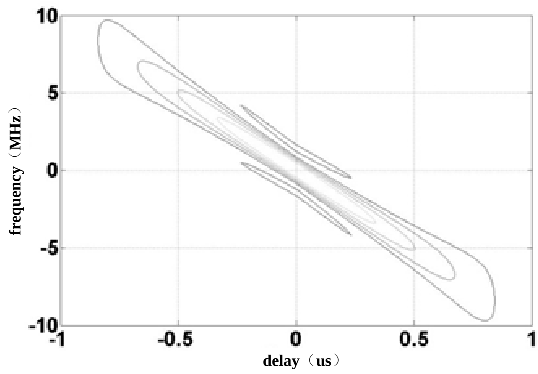
(a) Three-dimensional fuzzy graph



(b) Delay dimensional domain map



(c)Dimensional Doppler domain map



(d) Contour map

Figure 4. Chirp signal ambiguity function schematic

Figure 4 shows the Chirp signal after amplitude normalization of the three-dimensional view of a blur after the two-dimensional delay-domain diagram of a two-dimensional Doppler domain map and contour map. With the proviso that B = 10MHz, T = 1μs.

From Figure 4 (a) it can be seen chirp signal ambiguity function as miter knife-edge, with the origin of symmetry and get maximum value at the origin.

From Figure 4 (b) can be seen, when given Doppler value, the main value of the interval is narrowed only 0.2μs, the signal from the resolution has been greatly improved. So when the target speed to ascertain, given the very high range accuracy.

From Fig. 4 (c) can be seen when a given target delayed Doppler signal resolution unchanged, the main value of the interval remains 2MHz. This gives us a revelation that we can use to achieve precision pulse width of speed, range accuracy at the same time to achieve wide bandwidth modulation is large. Of course, with the proviso that one of the known speed and the distance therebetween.

From Fig. 4 (d) can be seen in the distance when the speed is unknown, can only obtain accurate values of the joint, but can not determine the target speed and distance, the more serious when the target is close to the blade when it is tilted, the goal will be difficult to distinguish.

Summary

This paper focuses on temporal and spectral characteristics of chirp signals, fuzzy aspects of introduction and analysis functions, and so lay the theoretical foundation for the study of pulse radar detection algorithm accumulation.

Reference

[1] Chen C, Andrews H C. Target-Motion-Induced Radar Imaging [J]. IEEE Trans. On AES, 2010, 16(1): 2-14

[2] Yang Li, Tao Zeng, Teng Long, et al. Range migration compensation and Doppler ambiguity resolution by Keystone transform [C]. Proceedings of 2006 CIE International Conference on Radar. Shanghai: IEEE press, 2013: 1466-1469

[3] Shun-sheng Zhang, Tao Zeng, Teng Long, et al. Dim Target Detection Based on Keystone Transform [C]. IEEE International Radar Conference. 2012: 889-594

[4] Carlson B.D., E.D. Evans, S.L. Wilson. Search Radar Detection and Track with the Hough Transform, Part Ⅰ: System Concept [J]. IEEE Trans. On Aerospace and Electronic systems, 2008, 30(1): 102-108

[5] Yang Li, Tao Zeng, Teng Long, et al. Range migration compensation and Doppler ambiguity resolution by Keystone transform [C]. Proceedings of 2012 CIE International Conference on Radar. Shanghai: IEEE press, 2012: 1466-1469

[6] Shun-sheng Zhang, Tao Zeng, Teng Long, et al. Dim Target Detection Based on Keystone Transform [C]. IEEE International Radar Conference. 2011: 889-594

[7] Carlson B.D., E.D. Evans, S.L. Wilson. Search Radar Detection and Track with the Hough Transform, Part Ⅰ: System Concept [J]. IEEE Trans. On Aerospace and Electronic systems, 2004, 30(1): 102-108

[8] Carlson B.D., E.D. Evans, S.L. Wilson. Search Radar Detection and Track with the Hough Transform, Part Ⅱ: Detection Statistics [J]. IEEE Trans. On Aerospace and Electronic systems, 2013, 30(1):109-115