Study on Velocity Estimation of MCPC Signal in Wideband Radar

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***Abstract*— This paper presents a novel scheme for velocity estimation in wideband Multi-Carrier Phase-Coded (MCPC) radar, which has drawn considerable attention recently as a new generation of radar. Conventional narrowband Doppler processing preserves the phase relationship of the received pulses, thus not only increases the Signal-to-Noise Ratio (SNR), but also obtains reliable extraction of the Doppler parameters. However, the rangewalk of moving target due to the wide bandwidth makes things difficult. Additionally, it is a question of interest to researchers that is resolving velocity ambiguity within a single burst. Based on separated processing of subcarriers in MCPC echo signals, we can estimate the radial velocity of the target without ambiguity by Least Squared (LS) algorithm over the linearity curve of Doppler spectrum. The simulation results verify that this scheme can be applied to the fast-moving target efficiently.**

I. Introduction

In the past, most of the effort put on multi-carrier signals was devoted to serve the communication community [1]. Recently, the radar community has also started to consider them as the possible new waveform generation. In [2] Levanon et al. proposed the MCPC radar signal, whose Orthogonal Frequency Division Multiplexing(OFDM) structure and coding technique can easily exhibit wideband characteristics. However, they mainly concentrate on MCPC waveform design and its ambiguity function(AF) [4-5], while concerning less on signal processing. The approach of measuring Doppler within a single pulse of OFDM-coded signals is studied in [6], in which the the Doppler tolerance and compression loss of the signal are investigated. In addition, feasibility of dual use of the waveform in both radar network and communication infrastructure is also being explored [10][11].

Velocity measurement is one of the important aspects in wideband radar signal processing. New radar signals and novel signal processing measures are to be searched due to the shortcoming of the common wideband signal in velocity measuring. In wideband radar, however, Doppler processing of moving target suffers a SNR loss due to the rangewalk [3]. Therefore, more effective velocity estimation is dependent on extracting Doppler information accurately and unambiguously. The MCPC pulse burst, which can be seen as a linear combination of several narrowband signals, supports a Doppler processing per subcarrier for low-velocity targets [7][8]. In multi-carrier-frequency MIMO radar proposed in [9], the Doppler shifts corresponding to the different transmit frequencies are used to resolve the ambiguity when the velocity is high, without transmitting multiple pulse repetition frequency (PRF) signals.

This paper attempts to explore the scheme for velocity estimation of the MCPC signal in wideband radar. In the next section the MCPC radar waveform is introduced briefly. Section III derives the mathematical expression of AF and analyses the characteristics using AF as a tool. In Section IV we present a velocity estimation scheme by combining the narrowband Doppler processing in every subcarrier and Least Squared (LS) algorithm over the linearity curve in Doppler spectrum. Section V presents the simulation results. Conclusions end the paper in Section VI.

II. The MCPC Radar Waveform Structure

A schematic description of an $N\times M$ MCPC pulse is given in Fig.1. It can be seen that the MCPC signal consists of N sequences which are transmitted simultaneously. Each subcarrier is modulated by a M bits phase-coded sequence.

The mathematical expression of the complex envelope of an $N\times M$ MCPC pulse is given as by

$$\begin{aligned} s(t) &= \sum_{n=1}^{N} W_n u_n(t)\exp(j2\pi f_n t) \\ &= \sum_{n=1}^{N}\sum_{m=1}^{M} W_n a_{n,m} rect\left[t-(m-1)t_b\right]\exp(j2\pi f_n t) \end{aligned} \tag{1}$$

where $u_n(t)$ is the *nth* subcarrier signal, $f_n=(n-1)\Delta f$ is the subcarrier frequencies, W_n is the complex weight associated with the *nth* carrier, $a_{n,m}$ is the *mth* phase element of the *nth* code sequence($|a_{n,m}|=1$), t_b is the bit duration and $rect(t)=\begin{cases}1, 0\le t\le t_b\\ 0, else\end{cases}$. To guarantee the orthogonality among subcarriers, the subcarrier spacing Δf equals $1/t_b$. For simplicity, W_n is supposed to be 1 which means all carrier amplitude weights are identical.