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A novel non-coherent radar pulse compression technique based on periodic m-sequences

Jahangir K. Kayani [a], Ali J. Hashmi [b,*]

[a] HITEC University, Taxila, Pakistan
[b] National University of Sciences and Technology, H-12, Islamabad, Pakistan

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ABSTRACT

Pulse Compression technique is extensively used in radar systems. It improves the Signal-to-Noise Ratio (SNR) of received signal without increasing the peak transmitted power. Non-Coherent Pulse Compression (NCPC) has been recently investigated as a new variant of standard (coherent) pulse compression technique. NCPC uses Manchester-coded pulse compression sequences, such as Barker and Ipatov sequences. This paper proposes a novel technique for implementation of NCPC that is based on well-known m-sequences along with a modified coding scheme. Theoretical evaluation shows that new NCPC technique gives perfect periodic-cross-correlation results (i.e., zero side lobes). Analytical and simulation analysis are performed that show that SNR performance of proposed scheme is comparable to the previously reported Manchester-coded NCPC using Ipatov sequences. It is also demonstrated that compared to previously reported techniques, transmitter and receiver implementation is much simpler in the scheme presented in this article.

1. Introduction

The received signal of a practical radar/sonar/Lidar is always corrupted by noise. Thus, target detection capability of these systems is heavily dependent on signal-to-noise ratio (SNR) of the received signal. Pulse compression is a standard technique of improving SNR, and thus detection performance of modern systems. Conventional pulse compression technique requires coherent transmitted waveform as well as coherent processing at the receiver [1,2]. Over the years, pulse compression has become a very practical technique for improving resolution in ranging and imaging applications, without increasing the peak power of the transmitted waveform [3–8].

NCPC is a new derivative of pulse compression technique [9–13]. For those ranging applications where Doppler information is not needed, NCPC can be applied advantageously. It offers better detection performance (compared to no pulse compression), while maintaining high range resolution [14,15]. NCPC requires binary amplitude modulation (e.g., OOK) on the transmitter side and a simple FIR filter at the receiver end [11,16]. It is considered for pulsed as well as periodic Continuous Wave (CW) signals. To exploit the full potential of NCPC, and to make it more practical; there is a need to explore novel good quality sequences and modulation techniques.

In [11] and [12], NCPC for periodic Continuous Waveforms was analyzed. The proposed NCPC scheme used Manchester coding in combination with OOK modulation of transmitter waveform. At the receiver side, a mismatched filter in form of an FIR filter was implemented [11,17,20]. It was demonstrated that NCPC scheme results in zero side lobes (which shows perfect periodic cross-correlation), except for two negative near-side lobes.

This paper investigates the employment of NCPC for periodic pulse compression signals with much simpler system architecture. Specifically, a novel coding scheme, based on m-sequences and a mismatched filter is presented. Both analytical and simulation calculations are performed and results are compared with the previously reported coding scheme. The results show that performance of the proposed new scheme is equivalent to the previously reported scheme and side-lobes performance is even better. More importantly, design of receiver in proposed scheme is much simpler.

Block diagram of the proposed NCPC scheme is depicted in Section 2 of the paper. Section 3 discusses the pulse compression algorithm and mismatched filter design. Incorporation of band-limited pulse shaping is discussed in Section 4, while implementation of the transmitter and receiver is presented in Section 5. Analytical performance analysis of the proposed scheme is dis-

* Corresponding author.
E-mail address: Hashmi@gatech.edu (A.J. Hashmi).

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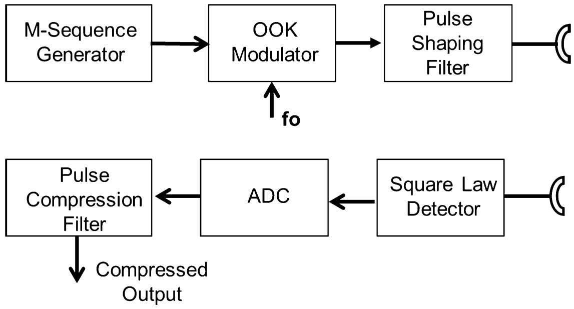

Fig. 1. Block diagram of the proposed NCPC scheme.

cussed in Section 6. Finally simulation results are presented and analyzed in Section 7.

2. Block diagram of the proposed NCPC scheme

The generalized block diagram of a radar employing proposed scheme of NCPC is shown in Fig. 1. Since a periodic Continuous Wave signal is employed, there is a need for separate transmitter and receive antennas with sufficient isolation to avoid direct leakage of transmitted signal. In the proposed design, on transmitter side, a Continuous Wave signal with center frequency f_o is coded employing the OOK scheme. Further, a periodic pulse compressed waveform is generated by applying the m-sequence waveform of desired characteristics. Finally, waveform is transmitted after application of a suitable pulse shape, by the pulse shaping filter. At receiver end, envelope detection is performed by the Square Law detector. Further, signal is digitized and a pulse compression filter (in shape of mismatched filter) is applied to materialize the objective of pulse compression.

3. Algorithm for the proposed coding scheme and mismatched filter design

The procedure for design of the proposed m-sequence based NCPC technique is explained in following steps:

Step-1: Select a suitable m-sequence of required length, depending on (a) desired level of pulse compression, (b) period of transmit waveform, (c) duration of each sub-pulse (system bandwidth), and (d) maximum unambiguous range. As an example, following sequence is generated.

Example: $\mathbf{t} = [\mathbf{1\ 1\ 1\ 1\ 0\ 1\ 0\ 1\ 1\ 0\ 0\ 1\ 0\ 0\ 0}]$

Step-2: Generate a periodic transmit waveform by applying OOK coding (binary amplitude modulation), such that "1" = pulse present and "0" = pulse absent.

Step-3: Generate a reference sequence **b** in which, each "0" of **t** is replaced with "−1".

$$\mathbf{b} = [\mathbf{1\ 1\ 1\ 1\ -1\ 1\ -1\ 1\ 1\ -1\ -1\ 1\ -1\ -1\ -1}]$$

Step-4: Replace each chip of **t** with a suitable pulse to match the bandwidth characteristics of transmitter and receiver (for example, raised cosine or Gaussian pulse).

Step-5: Transmit the periodic waveform **t** continuously through a transmitter antenna.

Step-6: At the receiver, perform envelope detection of received signal and digitize it.

Step-7: Implement a pulse compression filter in form of an FIR filter with coefficients given by **b**.

For the selected example of a 15-chip m-sequence, Fig. 2 depicts the plots of (a) transmit sequence **t**, (b) reference sequence **b** and, (c) periodic cross-correlation of **t** and **b**. There are 10 samples per chip; therefore, one period of the sequence has 150 samples. It can be seen from Fig. 2(c) that there are no correlation side lobes and correlation peak repeats with an interval equal to the length of selected m-sequence. Hence, the proposed scheme results in perfect cross-correlation results.

4. Incorporation of band-limited pulse shaping

Since rectangular pulses are not good and practical for transmission because of their infinite bandwidth, every chip in **t** needs to be replaced with a suitable band-limited pulse shape. This will, however, slightly reduce the compression gain. Continuing with the example of 15-chip m-sequence in previous section, a raised

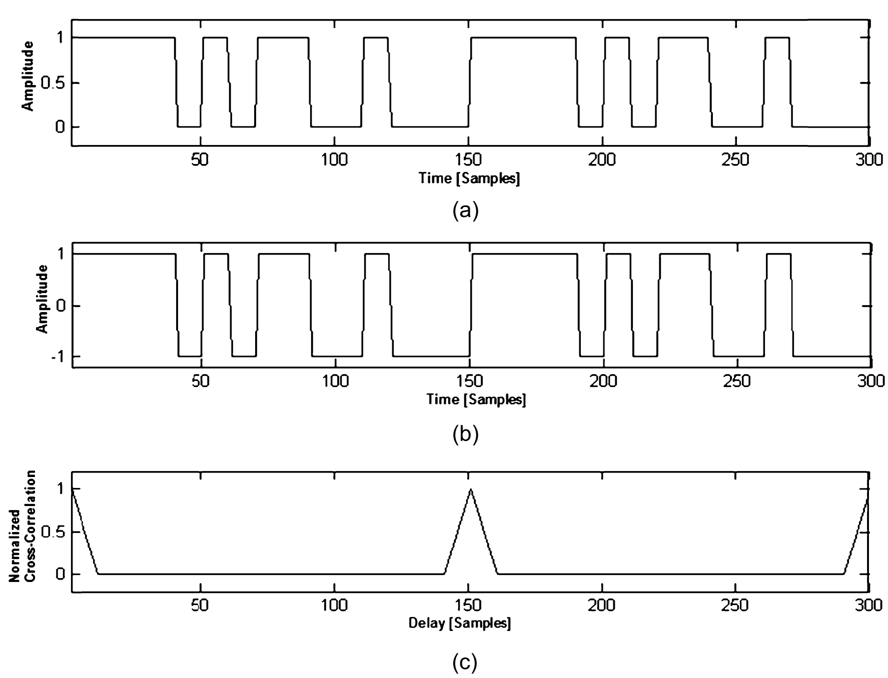

Fig. 2. (a) Transmitted sequence. (b) Reference sequence. (c) Periodic cross-correlation of proposed NCPC technique.