Inter-Period Compensation Algorithm in Full-Polarimetric FMCW Radar

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***Abstract*— This paper describes a new type of sounding signals for polarimetric FMCW radar and the corresponding signal processing technique. The inter-period compensation (IPC) algorithm is proposed for isolation increase in radar channels. The novelty concerns the use of orthogonal polarizations of two bi-cyclic LFM-signals having an additional phase shift every second sweep. Summation units proposed for use in the receiver channels allows for reducing the effects of interfering signals due to the specified phase of received signals over two consecutive sweep times.**

I. INTRODUCTION

Each echo signal (being scattered by radar object) undergoes a number of modifications connected with the reflecting (scattering) properties of the object. These modifications are completely described by the 2x2 target scattering matrix (SM) [1, 2] characterizing the transformation of amplitude, phase and polarization state of the signals during the process of sounding. Polarimetric radar transmits signals on orthogonal polarizations. The polarizations of the signals can be changed during the scattering process, as well as due to radiation, propagation and reception of electromagnetic waves. So in addition to polarization orthogonality extra (dual) orthogonality of sounding signals is needed for estimating the SM elements [3].

Additional orthogonality may be realized as orthogonality in waveforms using sophisticated signals, e.g. linear frequency modulated (LFM) signals. The distinct advantage of sounding LFM signals is the low computational cost in frequency modulated continuous wave (FMCW) radar receiver due to the de-ramping processing. Modern polarimetric FMCW radar provides polarimetric information with high range and Doppler resolution. Besides, the continuous wave transmission can use low peak power for the same detection performance as obtainable with pulsed transmission [4].

In case of simultaneous measurement of SM elements the polarimetric radar has a multi-channel structure [5]. However, sounding signals with orthogonal waveforms can not be completely orthogonal in terms of their inner product due to their limited duration. Their cross-correlation will not equal to zero at every time instant and non-orthogonality residuals will exist. Obvious consequence will be the limited orthogonality of the sounding signals, which results in the problem of cross channel interferences and in limited isolation in the polarimetric FMCW radar channels. These residuals can exceed the noise level significantly masking the weak targets over the whole observed range.

The idea proposed in this work is the application of a simple code modulation on the continuous (periodic) sounding LFM signal. The process of sounding changes the polarization state of the signals; however, it does not affect the waveform coding. So, the additional relationships obtained due to the additional coding of the transmitted signals allow us for compensation the non-orthogonality residuals existing in the received signals. In this way the inter-period compensation (IPC) algorithm is proposed for use for high isolation level in polarimetric FMCW radar channels.

This paper is structured as follows. In Section II the dual-orthogonal LFM signals are presented and clarified. Section III provides the description of the IPC method. In Section IV the theoretical performance of the inter-period compensation is derived. Simulation results are described in Section V. Conclusions are presented in Section VI.

II. DUAL-ORTHOGONAL LFM SIGNALS

A pair of LFM signals with opposite (up-going and down-going) slopes can be used for simultaneous measurement of scattering matrix elements [2, 5]:

$$\mathbf{u} = \begin{bmatrix} u_H \\ u_V \end{bmatrix} = \begin{bmatrix} u_1(t) \\ u_2(t) \end{bmatrix} = \begin{bmatrix} \exp\left[j2\pi\left(k_0 \cdot t^2/2 + f_0 \cdot t\right)\right] \\ \exp\left[j2\pi\left(-k_0 \cdot t^2/2 + f_0 \cdot t\right)\right] \end{bmatrix} \qquad (1)$$

where u_H and u_V are the signals transmitted on orthogonal (horizontal and vertical, subscripts H, V) polarizations. $u_1(t)$ and $u_2(t)$ are the up-going and down-going LFM signals. The signals are determined for one sweep time interval $t = [0...T]$, have frequency band ΔF ; $k_0 = \Delta F/T$ is the sweep rate of the sounding signal; f_0 is carrier frequency.

The novelty introduced in this work is the use of a new type of vector sounding signal, the bi-cyclic signal consisting of two LFM signals with opposite slopes