# Radar Polarimetry using Sounding Signals with Dual Orthogonality – PARSAX approach

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*Abstract*— **The article describes specific aspects of the radar polarimetry using sounding signals with dual-orthogonality. Such signals provide the unique opportunity to measure all elements of the polarization back-scattering matrix simultaneously, during one sweep/pulse period of radar signal. This approach has been implemented in the IRCTR PARSAX radar system, the fully polarimetric high-resolution Doppler FMCW radar. The digital architecture of the radar starts from intermediate frequency and makes the radar fully reconfigurable in terms of sounding waveforms and processing algorithms.**

## I. Introduction

It is widely known fact that using polarimetric information improves the radar performances for targets detection, identification and parameters estimation, as well as for clutter and interferences suppression [1], [2]. Most of modern radar polarimetry algorithms are based on the measurements of the radar target polarization backscattering matrix (BSM), which includes four elements with different amplitudes and phases. The necessity to measure all elements requires a multi-channel structure for the radar receiver and transmitter. But even then in most (existing) polarimetric radars the simultaneous measurement of all polarization scattering matrix elements at the same frequency band is not implemented yet.

The vector nature of electromagnetic fields and their scattering mechanisms requires in polarimetric radars the use of sounding signals with dual-orthogonality, i.e. the orthogonally-polarized components of such signals have waveforms that are orthogonal in terms of their inner product (cross-correlation) [3], [4]. Well established technical solutions can be used for the transmission and reception of the signals' orthogonally-polarized components. The orthogonality of components' waveforms can be established using different approaches. First, time orthogonality in polarimetric radar means the consequent transmission of sounding signals with orthogonal polarization combined with pulse-to-pulse polarization switching. Second, frequency orthogonality means that the sounding signals occupy non-overlapping frequency bands. However, the polarization of the scattered signals can vary over time and the scattering properties of the same radar object may be different for different sounding frequencies. So both time and frequency orthogonalities can introduce temporal, frequency and phase ambiguities in the polarimetric results.

There is a known solution (see e.g. [3], [4], [5]) of polarimetric radar design that completely removes these ambiguities, that is the use of signals with orthogonally-polarized components, which have waveforms that are orthogonal in terms of their inner product (cross-correlation). Such type of sounding signals provides the unique possibility to split all elements of scattering matrix and to measure all of them simultaneously during one pulse or single sweep time. One of examples of such orthogonal waveforms is a pair of linearly-frequency modulated (LFM) signals with opposite frequency excursions, which occupy the same bandwidth and the same time interval. The distinct advantage of these signals is the low computational cost due to the narrow-band de-ramping processing.

At the beginning of 2010 the PARSAX– high resolution Doppler S-band polarimetric radar, which use dual-orthogonal sounding signals for simultaneous measurement of all elements of polarization BSM, became operational. As soon as the measurements and analysis of their results only started at this moment, the purpose of this article is briefly describe our approaches for polarimetric data processing and interpretation, to formulate tasks for initial experiments and measurement campaigns. The analysis of experimental data will be presented during the conference and included in extended publications.

The structure of the paper is the following. Section 2 gives a brief description of the radar polarimetry basic concept - the polarization backscattering matrix, which is output measure of the PARSAX radar. The representation of BSM in terms of Huynen-Euler invariants provides very clear and useful information for the physical interpretation of the observation results. Section 3 describes our approach for the polarimetric measurements of the non-stable (moving and fluctuating) targets using advantages of the PARSAX - high-resolution Doppler polarimetric radar, which implements the concept of dual-orthogonal signals for simultaneous measurement of all scattering matrix elements, and is developed in IRCTR, TU Delft. Section 4 describes briefly the reconfigurable architecture of the radar and available library of waveforms and real-time FPGA-based processing algorithms. Finally, Section 5 includes the conclusions.

## II. Polarization Backscattering Matrix and Huynen-Euler Invariants

Instant polarization properties of any radar object can be fully described using polarization backscattering matrix