# A Multiple Target Doppler Estimation Algorithm for OFDM based Intelligent Radar Systems

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***Abstract*— In this paper an approach will be presented that allows for estimating the velocity of multiple reflecting objects with standard OFDM communication signals. The proposed technique does not require any specific coding of the transmit signal and provides high dynamic range and low sidelobe levels. This allows for an efficient acquisition of velocity information in joint communication and radar systems. The paper discusses the developed algorithm and a possible OFDM system concept for automotive applications. Measurement results are provided that prove the operability in practical scenarios.**

## I. Introduction

In the current technological development the radio frequency frontend architectures used in radar and digital communication technology are becoming more and more similar. In both applications more and more functions that have traditionally been accomplished by hardware components are now being replaced by digital signal processing algorithms. Moreover, today's digital communication systems use frequencies in the microwave regime for transmission, which are close to the frequency ranges traditionally used for radar applications. This technological advancement opens the possibility for the implementation of joint radar and communication systems, that are able to support both applications with one single platform and even with a common transmit signal. A typical application area for such systems would be intelligent transportation networks, which require the ability for inter-vehicle communications as well as the need for reliable environment sensing.

First concepts of joint radar and communication systems have been primarily based on spread spectrum techniques [1]. Recently, OFDM signals have gained a lot of attraction for this purpose. This is motivated by two facts. First, most currently released communications standards, e.g. IEEE 802.11.p, employ OFDM signals [2]. Second, in the radar community recently OFDM signal have attracted general interest and their suitability for radar applications has been proven [3]. Hence, currently OFDM signals seem to be the ideal basis for joint radar and communication implementations.

In OFDM radar typically the signals are processed with a correlation of the transmitted and received baseband signals as for any pulsed radar system. The authors have proposed a novel processing scheme for OFDM radar that offers a superior dynamic range independent from the transmitted information [4]. This is achieved by processing directly the information symbols that compose the OFDM signal instead of processing the baseband signals. However, not only the range measurement but also the capability of Doppler measurement is an important feature of radar systems. In particular, regarding vehicular applications the availability of velocity information is an essential requirement. In the investigation of OFDM radar concepts up to now only little attention has been paid to Doppler estimation. In [5] a concept for Doppler estimation is presented, however the results show ambiguities with a relatively high level.

In this paper the novel processing approach that has been introduced by the authors for OFDM radar range processing is extended to a similar concept for Doppler processing. The algorithm can be applied in combination with a transmission of arbitrary user data and is able to resolve multiple reflecting objects with a high dynamic range and very low sidelobe levels.

The remainder of the paper is organized as follows: In chapter II the mathematical description of the OFDM signal and the range processing based on the modulation symbols will be discussed. In chapter III, these considerations will be extended to a series of subsequent OFDM symbols and the symbol based approach will be adapted to Doppler processing. In chapter IV a suitable system parameterisation for the 24 GHz ISM band will be derived. The operability of the developed Doppler estimation algorithm will be verified with simulations. In chapter V a system setup will be presented and measurement results will be shown.

## II. Symbol-Based OFDM Radar Processing

The OFDM transmit signal represents a parallel stream of orthogonal subcarriers, each modulated with transmit data. One OFDM symbol can be expressed as

$$x(t) = \sum_{n=0}^{N-1} I(n) \exp(j2\pi f_n t), \quad 0 \le t \le T \qquad (1)$$

with $N$ denoting the number of orthogonal subcarriers, $f_n$ being the individual subcarrier frequencies, $T$ being the elementary OFDM symbol duration, and $\{I(n)\}$ representing an arbitrary information series consisting of complex modulation symbols obtained through a discrete phase