Radar and Radio Data Fusion Platform for Future Intelligent Transportation System

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Abstract—**We present a software-defined data fusion system which integrates both radar (sensing) function and radio (communication) function within a single transceiver platform. In the proposed architecture, the radar mode and the radio mode operate in different time slots. The required modulated waveform is generated with the help of a direct digital synthesizer (DDS) that is able to control signal parameters such as amplitude, frequency and phase with very high resolution. For the radar mode, a specially arranged trapezoidal frequency modulation continuous-wave (TFMCW) modulation scheme is adopted, which combines three time intervals, namely an up-chirp, a constant-frequency period and a down-chirp. As such, range-velocity ambiguity can be resolved. Moreover, a constant-frequency period follows the radar cycle in the transmitted signal, which can be encoded with information data using different modulation schemes such as ASK, FSK, PSK, and some combinations among them. A low-frequency prototype for the 5.9-GHz dedicated short range communication (DSRC) system was designed and prototyped. Both system simulation results and preliminary measurement results have proved the proposed concept. The presented system has demonstrated such advantages as low cost, low complexity, and versatile functionality, which promises to play an important role in the design of future intelligent transportation system.**

I. Introduction

Road traffic injuries have both social and economical costs, and this fact gives birth to intelligent transportation system (ITS). Within the framework of ITS, intelligent vehicles should work in an autonomous manner to sense the driving environment and in a cooperative manner to exchange information data such as braking and acceleration between vehicles and also traffic, road and weather conditions between vehicles and roadside units [1]. Therefore, both radar and radio functions are required in the future intelligent vehicles.

Previous works have demonstrated a number of radar systems with communication capability. In [2], data was encoded onto the conventional FMCW radar waveform by amplitude modulation (AM) in order to realize the communication function. However, the AM receiver in [2] is not able to transmit signals, and the frequency should be carefully selected for different units if duplex communication is required. In addition, frequency-shift keying (FSK) was integrated with conventional FMCW radar to allow for the cooperation between different radar units [3]. On the other hand, pulse radars with communication function were realized by allocating the communication channel at the first null of the radar spectrum [4]. Simultaneous communication and radar functions were also incorporated in an ultra-wideband system, which makes use of the quasi-orthogonality of the up- and down-chirp waveforms assigned to communication and radar signals, respectively [5]. However, there are two transmitters and two receivers in this scheme.

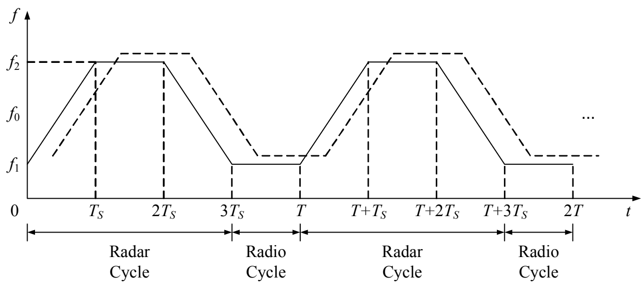

Figure 1. Proposed radar-radio modulation scheme. (Solid line: transmitted signal; dashed line: received signal).

In order to reduce system cost and design complexity as well as increase architecture flexibility and reliability, we propose a new radar-radio modulation scheme, which is composed of a radar cycle and a radio cycle arranged in time domain. The radar cycle utilizes a trapezoidal FMCW (TFMCW) waveform and the radio cycle is a constant-frequency period. In this way, both radar and radio functions can be realized by making use of a single transceiver platform.

This paper is organized as follows. In Section II, the operation principle of the proposed system will be described and then the system architecture will be presented. In order to prove the system functionality, a low-frequency prototype was designed and analyzed for the 5.9-GHz dedication short range communication (DSRC) system in Section III. Preliminary measurement results have been shown in Section IV to prove the proposed concept.

II. System Operation Principle

A. Modulation scheme

Fig. 1 shows two cycles of the proposed modulation waveform. In a single cycle of T seconds, radar and radio functions operate in different time slots. The radar cycle is totally $3T_S$ seconds long, including an up-chirp, a constant-frequency period, and a down-chirp with the same duration of T_S seconds while the radio cycle is located in a constant-frequency period, whose duration is set to T_S for simplicity in