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# Test bench development for signal registration in millimeter wave automotive radars

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**Abstract.** A development of a bench for automotive radar signals registration and analysis is considered in this paper. The bench is based on the AWR1642boost evaluation module with 77 GHz carrying frequency. Supporting software is developed to help signal analysis and reflection model creation. The bench aims an investigation of signal reflection properties from some specific types of obstacles and the development of the reflection mathematical models.

## 1. Introduction

Millimeter wave radars are widely used in different types of modern remote sensing systems including automotive radar imaging. Millimeter wave radars have some important advantages over centimeter waves including less antenna size and system form factor; much simpler technical design of wavelength dependent components; high transmission power and wide frequency band at the same time; cheapness of target products [1]. Radars make advanced driver assistance systems (ADAS) more functional and reliable in poor weather conditions, in low light, at long distances and in some other cases [2]. One of functions ADAS radar can offer is a detection of obstacles at the road in front of a vehicle at a distance enough to prevent an accident. Some fallen trees and other unwanted objects, pothole, icing can become very dangerous obstacles. The development of ADAS radar which would be able to solve the described problem efficiently requires the knowledge of the mathematical model of radio wave reflection from different obstacle types. Specific properties of road obstacle reflections are of a great interest.

In [3] the analysis of radar reflections from the asphalt surfaces in millimeter wave range is carried out. The reflections from dry, wet and iced asphalt are considered and compared. An ability to detect a road surface condition with icing and snowing detection is analyzed in [4]. Wide set of experiments on scattering cross section measurement for different types of typical road objects is carried out in [5].

In this paper the development of hardware and software facilities for the registration of test signals in millimeter wave radar system (77 GHz frequency band) is considered. Unlike the works mentioned above the main purpose of the test bench development is to understand the properties of reflections from obstacles of a specific kind: unwanted objects and potholes; and to form their mathematical model.

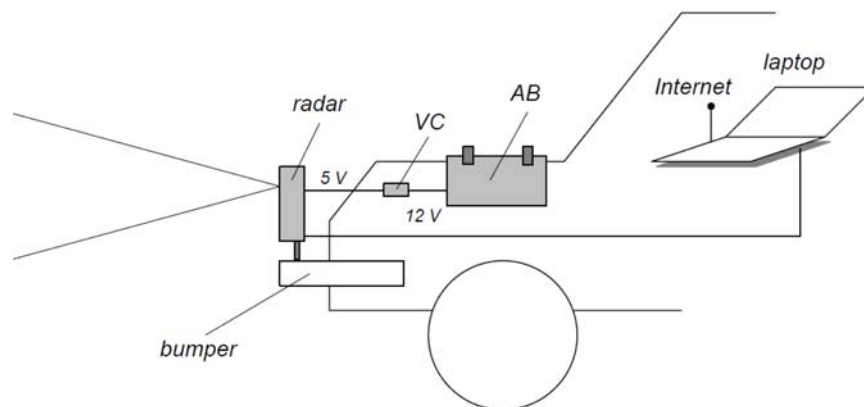
## 2. Hardware components of the bench

An AWR1642boost evaluation module from Texas Instruments is used as a basic hardware component of the bench. This is a highly integrated system-on-a-chip which includes ARM-family master core, C674x digital signal processor (DSP) core and the radar subsystem with analog and radio frequency transceiver path and analog to digital conversion [6]. Frequency modulated continuous wave (FMCW)



signals are used to get good range and velocity resolution. Frequency band is centered at 77 GHz. Azimuth resolution is achieved with an antenna array, including four receiving and two transmitting antennas with an ability to use multiple input multiple output (MIMO) approach to improve the resolution.

The AWR1642boost module is installed on a front bumper of a car to carry out field experiments.



**Figure 1.** A diagram of AWR1642boost based test bench, installed on a car.

The AWR1642boost board is placed in a radio transparent case to protect it from dirt, water or mechanical damages. Easy installation and removal of the module is provided by bolting. The module is powered by the automotive battery (AB). The battery voltage of 12 V is converted to the supply voltage of 5 V required by the module. Voltage converter (VC), made on the basis of the stabilizer SCV0042-5V-0.9 A, is used for this purpose. The structure of the bench is shown in figure 1.

The module is connected to the laptop via the debug port, allowing reading signal records. Laptop connection to the Internet should be provided to allow the use of the software shell Demo Visualizer from Texas Instruments. This tool provides user interface when working with the module.

The functionality of the bench is as follows. The car is sent to the place of the experiments. In place the module in the case is installed onto the front bumper of the car. Easy installation is performed with two nuts. Power and laptop interface cables are connected to the radar. These cables are pre-installed and are not removed from the vehicle. On the laptop in the Demo Visualizer environment, the required radar operation mode is set, including the selection of signal parameters and the desired radar characteristics. An object, the reflecting properties of which are studied is placed in front of the car at the required distance, or the car is placed so that the object of interest is in the field of view of the radar. Demo Visualizer on the laptop screen builds radar image of the observed scene in real time. When the scene is set up, the signal recording is started for further processing and analysis in the laboratory. The signal can be recorded when the vehicle is stationary or in motion.

### 3. Software components of the bench

The software used for signal recording and analysis can be divided into two components. The first one is the software used during signal recording. The second component is a specially developed environment, which combines the capabilities of signal modeling, real records analysis, reflection model development and testing.

The software used during signal registration process includes the tools which are provided together with evaluation module. This includes Demo Visualizer, which has already been mentioned above, and a set of program codes loaded on the processor. The processor codes are open source and allow modification and reload of the executable files. The codes are divided into the programs for the ARM control core, and the programs executed by the DSP signal processing core. The Code Composer

Studio integrated development environment is used to modify these programs and reload the processor.

DSP software implements a signal processing algorithm typical for ADAS FMCW-radars. Fast Fourier transform (FFT) with pre-weight processing provides range resolution. The second FFT provides the resolution for velocity. Averaging over the receiving channels from four antennas and the use of two-time threshold processing (before and after velocity resolution) increases the reliability of object detection. The third FFT is performed across the receiving channels and provides azimuth resolution. The azimuth FFT can be 4 (according to the number of real antennas) or 8 point if MIMO technology is used (according to the number of transmitting and receiving antenna pairs). A 1-point discrete Fourier transform (DFT) is performed before the azimuth FFT. In fact, it just repeats the velocity FFT but only for those ranges and velocities which were previously detected, so this DFT is very low complexity. This approach is used because only limited internal DSP memory can be available in practice. It becomes possible not to store the results of the second FFT, but to perform it again, but in much simpler conditions.

The DSP software includes general purpose library functions and also the codes written specifically for this task. The software can be easily extended or modified. In particular, in the case of the development of the described test bench DSP software is modified to give the ability to record "raw data", that is, fixing the signal samples coming directly from the analog-to-digital converter (ADC) without any digital processing. The volume of recording in the current implementation of software is limited by the DSP memory and corresponds to the reflection of one frame of radar pulses.

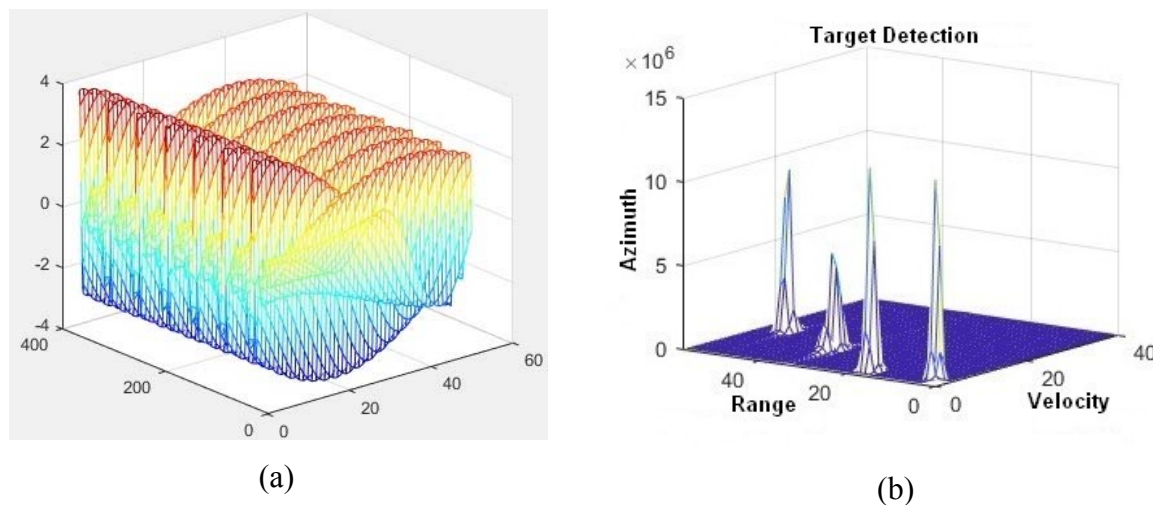
ARM-core software performs system initialization and organizes chip components interconnections.

The Demo Visualizer environment executed at the laptop receives the data calculated by the DSP-core and visualizes it as a radar imagery.

A specially developed software shell targeting signal modeling, real data analysis and reflection model formulation and testing is another part of test bench software. This shell includes three main components which address the three parts of graphical user interface located at the top, middle and bottom of the screen, respectively. The first component is responsible for selecting the mode of operation: signal model or real recording. If we are working with a signal model, the type and parameters of the obstacle, such as material, size, distance, location geometry and some other parameters are selected. In the case of real record operation, the parameters at which this record was made are entered.

The second component performs the tasks of calculating the signal model, visualizing the characteristics of the signal, analyzing its properties.

The third component performs signal processing and visualizes the results. A user can set the processing mode, select the preferred modification of the algorithm, analyze the quality of the image. The samples of the signal generated during mathematical modeling for the case of four point reflectors are shown in figure 2(a). The model is calculated for the case of four receiving antennas and a frame of radar pulses. The result of the processing is shown in figure 2(b). It represents the output of 2-dimensional FFT procedure across range and velocity bins.



**Figure 2.** A model of a reflected signal (a) and the results of its processing in the developed software shell (b).

#### 4. Conclusion

The paper describes the development of software and hardware for registration of test signals to study the properties of reflection of electromagnetic waves in the millimeter range from objects that can influence much the safety on the roadway. Hardware components of the test bench and software tools that perform analysis of test records and their processing are considered. Further work is related to the development of a mathematical model of the reflections, which is waited to be formed on the basis of the test records. Then the model should be integrated in the software environment of ADAS radar modeling and investigation, which finally is waited to result in a development of the improved algorithms for the detection of obstacles of the given type.

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