Automotive Radar using AWR2243 Booster Pack

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Abstract—In developing countries the growth in the number of motor vehicles is the most significant factor in the rise of road fatalities and injuries. It may be observed that 1.35 million people die every year owing to crashes on road. Most of the accidents can be prevented if the events are detected automatically 1-2 seconds in advance. Texas instruments has come up with a new evaluation board AWR2243 having a single chip operating at 76 to 81Ghz having a FMCW transceiver. This can be instrumental in adaptive cruise control, emergency braking and automated highway driving. A FMCW (frequency modulated continuous wave) obtains the range and velocity from a beat signal. Here millimeter-wave sensors use minimal power consumption to sense range and velocity and the required angle. The device is interfaced to an external DSP host processor which uses a SYNC_IN signal to start the radar frames. The periodicity of the frames is suitability programmed. The processing provides a high level of performance and flexibility. The signal has three parallel transmit chains and four parallel receive chains. Each receive channel has an LNA, mixer, IF filtering, A2D conversion and decimation. A two- dimensional FFT algorithm is implemented on the host DSP processor.

Keywords—FMCW, beat, transmit, receive, mmwave, range, velocity

1 Introduction

1.1 Background

In developing countries, the growth in the number of motor vehicles is the most significant factor in the rise of road fatalities and injuries [1]. It may be observed that 1.35 million people die every year owing to crashes on road. Most of the accidents can be prevented if the events are detected automatically 1-2 seconds in advance [2]. Texas instruments has come up with a new evaluation board AWR2243 having a single chip operating at 76 to 81Ghz having a FMCW transceiver. This can be instrumental in adaptive cruise control, emergency braking and automated highway driving [3]. A FMCW (frequency modulated continuous wave) obtains the range and velocity from a beat signal [4]. Here mmwave sensors use minimal power consumption to sense range and velocity and the required angle [5]. The device is interfaced to an external DSP host processor which uses a SYNC_IN signal to start the radar frames. The periodicity of the frames is suitability programmed. The processing provides a high level of performance and flexibility. The signal has three parallel transmit chains and four parallel receive chains. Each receive channel has an LNA, mixer, IF filtering, A2D conversion and decimation. A two-dimensional FFT algorithm is implemented on the host DSP processor.

1.2 What is mmwave?

A sensing technology where velocity, range and angle of the objects is available for the detection of objects [6]. As the technology uses small wavelengths sub-mm range accuracy can be obtained where the sensors can penetrate clothing, plastic and drywall [7]. These sensors can also work in rain, fog dust and snow.

1.3 FMCW RADAR concept

Here a linear frequency modulated continuous wave follows a sawtooth pattern.

$$x(t) = Acos(2\pi f_c \mathrm{t}+\pi \frac{B}{T} t^2 + \varphi_0) \tag{1}$$

The Phase of the transmitted signal is

$$\emptyset_T(t) = 2\pi \left(f_c t + \frac{1}{2}\mu t^2\right) + \varphi_0 \tag{2}$$

The reflected signal is given by

$$r(t) = \alpha Acos[2\pi f_c(t-\tau) + \pi\mu(t-\mu)^2 + \emptyset_0 \tag{3}$$

The Phase of the received signal is

$$\emptyset_R(t) = 2\pi[f_c(t-\tau) + \frac{1}{2}\mu(t-\tau)^2 \quad +\emptyset_0 \tag{4}$$

The phase of the beat signal is

$$\Delta\emptyset(t) = \emptyset_T(\mathrm{t})\text{-}\emptyset_R(t) \tag{5}$$

$$\Delta\emptyset(t) = 2\pi[(\frac{2f_c v}{c} + \frac{2\mu R_0}{c} - \frac{4\mu R_0 v}{c^2})t + (\frac{2\mu v}{c} - \frac{2\mu v^2}{c^2})t^2 + \frac{2f_c R_0}{c} - \frac{2\mu R_0{}^2}{c^2}] \tag{6}$$

A local oscillator helps generate the required FMCW waveform which is transmitted by an antenna after amplification by a power amplifier [8]. The radar illuminates a region of interest, from which the objects present are deciphered. The reflected signal is received by an antenna and is amplified by an LNA [9].

To understand the FMCW concept a small Simulink simulation is shown below:

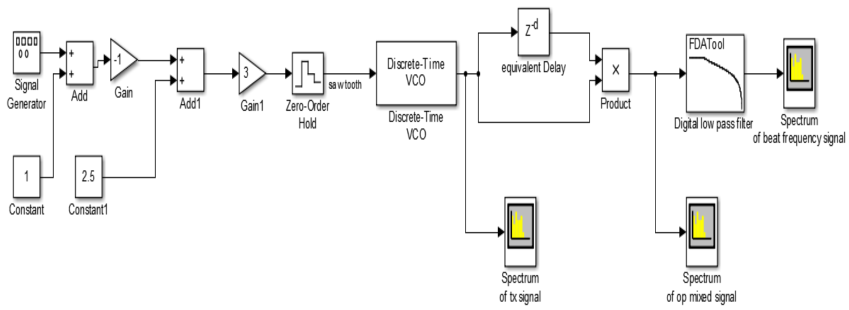

Fig. 1. Illustration of FMCW concept

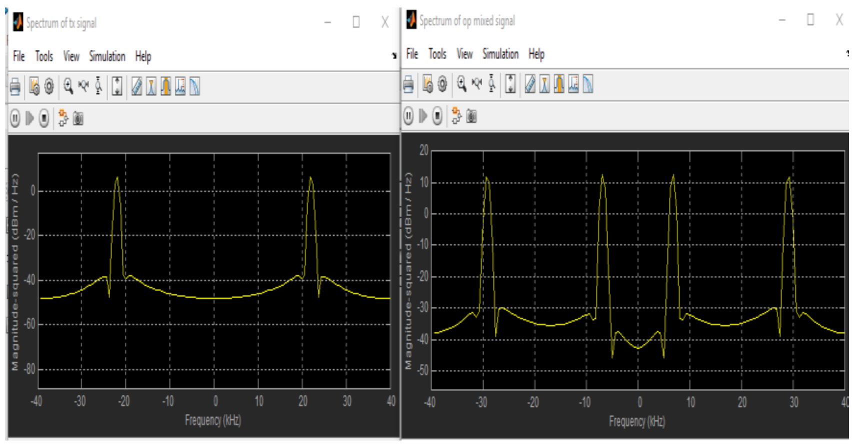

Fig. 2. Transmitted signal(left) Output Mixed signal (Right)

Fig. 3. Spectrum of beat frequency

2 Hardware Description

Shown in Figure 4 is an architectural diagram of the kit. The kit shows three transmitters and four receivers. The various bus interfaces help interfacing to a host microcontroller, which can a set of multicore DSP processors. Figure 5 shows the functional block diagram of the AWR2243 board. Here an internal synthesizer generates the 20GHz reference signal. A phase shifter helps form the beam and the signal is amplified using power amplifiers. There are four receive antennas. Each received signal is amplified by a Low noise amplifier, mixed with a local oscillator to get an intermediate frequency (IF) signal. This is then given to an analog to digital converter. All the digital channels are then passed through a decimation filter chain. This output is further processed by the host DSP processor. Figure 6 shows the Front view of the board where the AWR2243 chip and a Flash is visible. Also visible is a 5V power connector and the CAN interface. Figure 7 shows the rear view of the board where XDS 110 PMIC chip and micro USB connector are shown. Two 20 pin launchpad connectors namely J5 and J6 are also visible. Also seen in the rear view is the heat sink area.

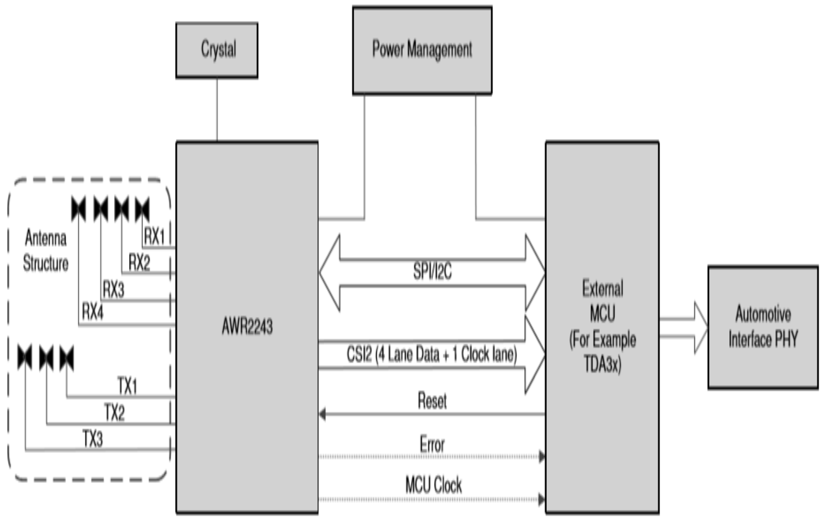

Fig. 4. Interfacing External host to AWR2243

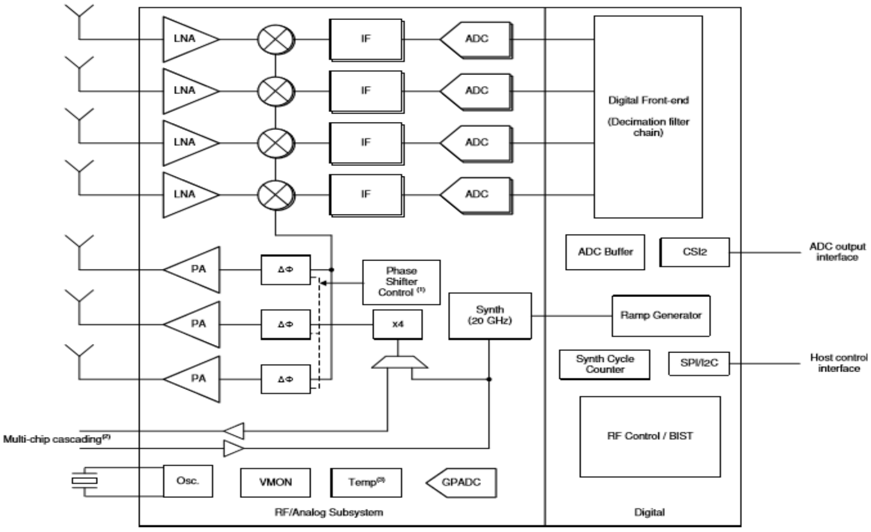

Fig. 5. AWR2243 functional block diagram

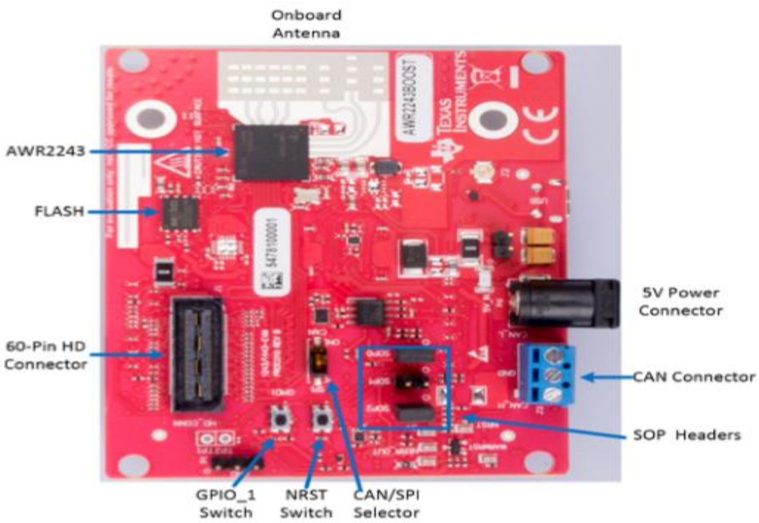

Fig. 6. AWR2243 board (Front View)

3 Project Methodology

A lion's share of collision avoidance applications uses radar sensors. The major advantage is that it can see in both day/night and all-weather conditions. Here highly directional antennas which are lightweight are used. An electronically steered antenna beam is used to improve signal to noise interference ratio (SINR). Adaptive signal processing is also used to minimize interference. The solutions require complex signal processing where multicore processing is required to meet compute requirements along with area and power budgets.

The sampled beat signal is shown by the equation given below:

$$S_{BF}(t)=\sum_{0}^{M-1} e^{j2\pi[(\frac{2f_c v}{c}+\frac{2\mu R_0}{c}-\frac{4\mu R_0 v}{c^2})t+(\frac{2\mu v}{c}-\frac{2\mu v^2}{c^2})t^2+\frac{2f_c R_0}{c}-\frac{2\mu {R_0}^2}{c^2}]} \quad (7)$$

Here a Fourier transformation is performed for each ramp

$$S_{BF\Delta D}(m,k) = e^{j4\pi\frac{f_c R_0}{c}} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} e^{j4\pi\frac{vT_c f_c m}{c}} . e^{j2\pi[(f_d+f_c)T_s n-\frac{kn}{N}]} \quad (8)$$

Here fourier transform is applied in the range and doppler dimension. The potential obstacles are identified using FFT magnitude peaks. After determining range Doppler FFT is performed.

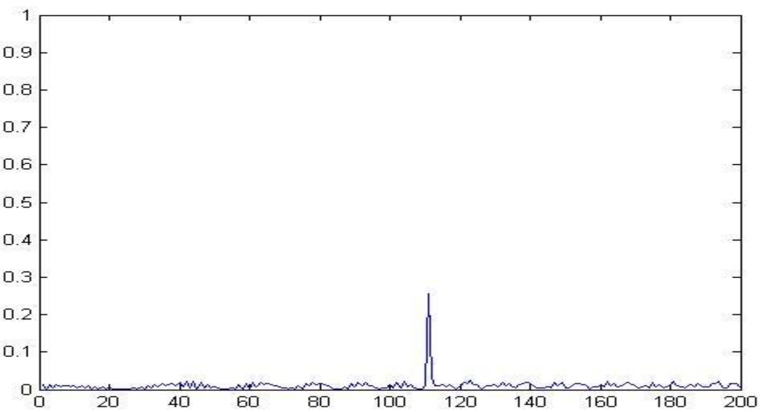

Fig. 7. Range from first FFT

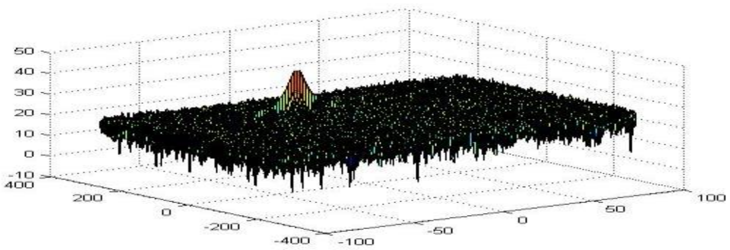

Fig. 8. Range and speed form second FFT

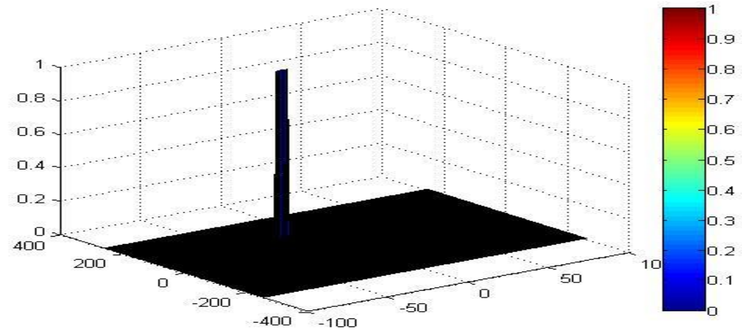

Fig. 9. Cfar from second FFT

The mutual interference (due to interference between to and fro radars) probability becomes a significant factor. This leads to performance degradation causing significant safety risks. The sensitivity of the radar system is degraded with the generation of host targets.

4 Millimeter Wave Link Monitoring Application

1. Read all global variable configurations from config file
2. Initialize the internal components, create Mutex/Semaphore
3. Initialize buffers, register interrupts, bring mmwave front end out of reset.
4. Change CRC Type of Async Event generated by MSS to what is being requested by user in mmwaveconfig.txt
5. The mmwave Front end once enabled runs boot time routines and upon completion sends asynchronous event
6. The mmwave Front end needs to be configured for mmwave Radar operations. basic configuration includes Rx/Tx channel configuration, ADC configuration etc
7. The mmwave Front end once configured needs to be initialized. During initialization mmwave Front end performs calibration and once calibration is complete, it notifies the application using asynchronous event
8. For Frequency Modulated Continuous Wave (FMCW) Radar, user need to define characteristics of FMCW signal using profile configuration.
9. A chirp is always associated with FMCW profile from which it inherits coarse information about FMCW signal.
10. Configure monitoring time and frequency unit and along with this enable miscellaneous monitoring feature of device.
11. Start mmwave Radar Sensor. This will trigger the mmwave Front to start transmitting FMCW signal. Raw ADC samples would be received from Digital front end.
12. Wait till Host receives all monitoring report where number and periodicity of monitoring report is configured.
13. Close Configuration file

5 Detection Based on 2D FFT Algorithm

1. Generate SYNC-IN signal to start radar frames
2. Receive ADC data from transceiver
3. Calculate Beat Signal
4. Calculate fourier transform for each ramp.
5. From the peak of the fourier spectrum get range and velocity information.
6. From the second FFT obtain a more accurate range information of target.
7. From maximum doppler frequency obtain maximum unambiguous velocity
8. From the maximum beat frequency obtain the maximum unambiguous range.

6 Results and Discussion

The FMCW radars are highly flexible. Low cost sensors can be programmed to recognize different objects. However, they require a clear field of view. There is a need to have powerful hardware. The software so required is also complex. In sections 4 and 5 we have successfully outlined the algorithms to configure the kit and suitably outlined the procedure for target detection.

7 Conclusion

FMCW radars in the GHz range give with high accuracy, repeatability and reliability for distance measurement. They perform extremely well when the conditions are harsh and non-contact measurement of distance is to be measured. In this paper we have successfully defined the use of AWR2243 Booster Pack for automotive radar purposes. The radar equations can be purposefully implemented and a runtime software executable can be built and configured. The procedures for detecting obstacle has thus be carefully outlined.

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