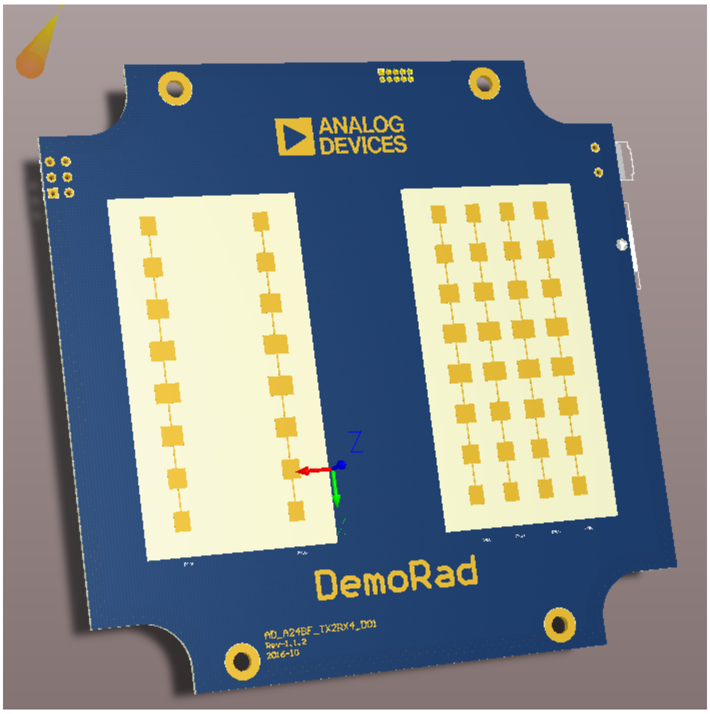
DemoRad

(Hardware User Manual)



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1 Document Version

Version	Description	Date	Author
1.0.0	Initial Version	2016-12	Andreas Haderer
1.1.0	Measurement results	2017-01	Andreas Haderer
1.2.0	FMCW Timing	2017-02	Andreas Haderer

2 DemoRad System Overview

The A24BF is a standalone radar system with a 24-GHz MIMO FMCW frontend featuring two transmit (TX), four receive (RX) channels, and a Blackfin DSP (ADSP-BF706BCPZ-4) from Analog Devices. The system is mainly designed for range-Doppler and MIMO radar applications and the DSP enables real-time signal processing capabilities. The antenna arrangement is choosen to support a unifom virtual array with a spacing of half the wavelength. When using both TX antennas 7 virtual elements can be generated with two virtual elements overlapping in order to implement motion compensation algorithms. The main features of the 24-GHz radar system include

- 24-GHz ISM band operation,
- sampling rate up to 1.2 MSPS per IF channel,
- ramp-synchronous sampling,
- programmable FMCW waveform,
- MIMO processing with arbitrary antenna activation,
- real-time signal processing on the Blackfin DSP, and
- USB 2.0 or CAN interface for communication.

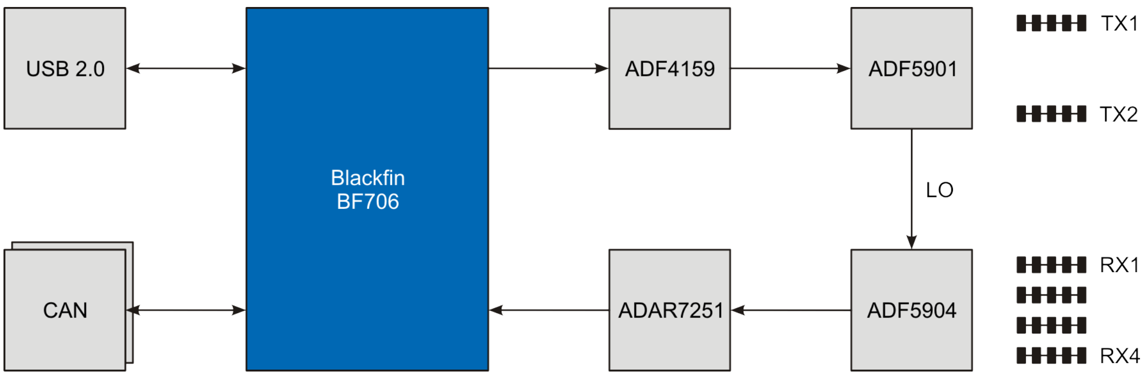

Figure 1: Blockdiagram of the FMCW system with Blackfin DSP for signal processing.

In Fig. 1 a block diagram of the system is shown. A Blackfin BF706 DSP is used to control the RF frontend and to process the measured radar signals of the receive channels. According to the block diagram, an ADF5901 dual-channel transmitter in conjunction with the frequency-synthesizer ADF4159 is used to generate the FMCW transmit signal. The two TX antennas (TX_1, TX_2) are fed from the ADF5901 transmitter whereas the receive path of the frontend is realized with a ADF5904 quad-channel receiver. An ADAR7251 analog frontend is used to amplify and sample the measured IF signals of the receiver. Thereafter, the signals are processed in the DSP and the results can be accessed with a USB 2.0 or a CAN interface. The entire board including the power supply is designed on a single PCB with a total size of 100 mm x 100 mm. In the subsequent section the mechanical and electrical properties of the baord are summarized in more detail.

3 Technical Data of the 24-GHz Radar System

In the following sections the mechanical and the electrical parameters of the frontend are summarized. In addtion, the antenna system and the antenna patterns are shown.

3.1 Mechanical Data

The dimensions of the 24-GHz single board radar system including the positions of the mounting holes are shown in Fig. 2.

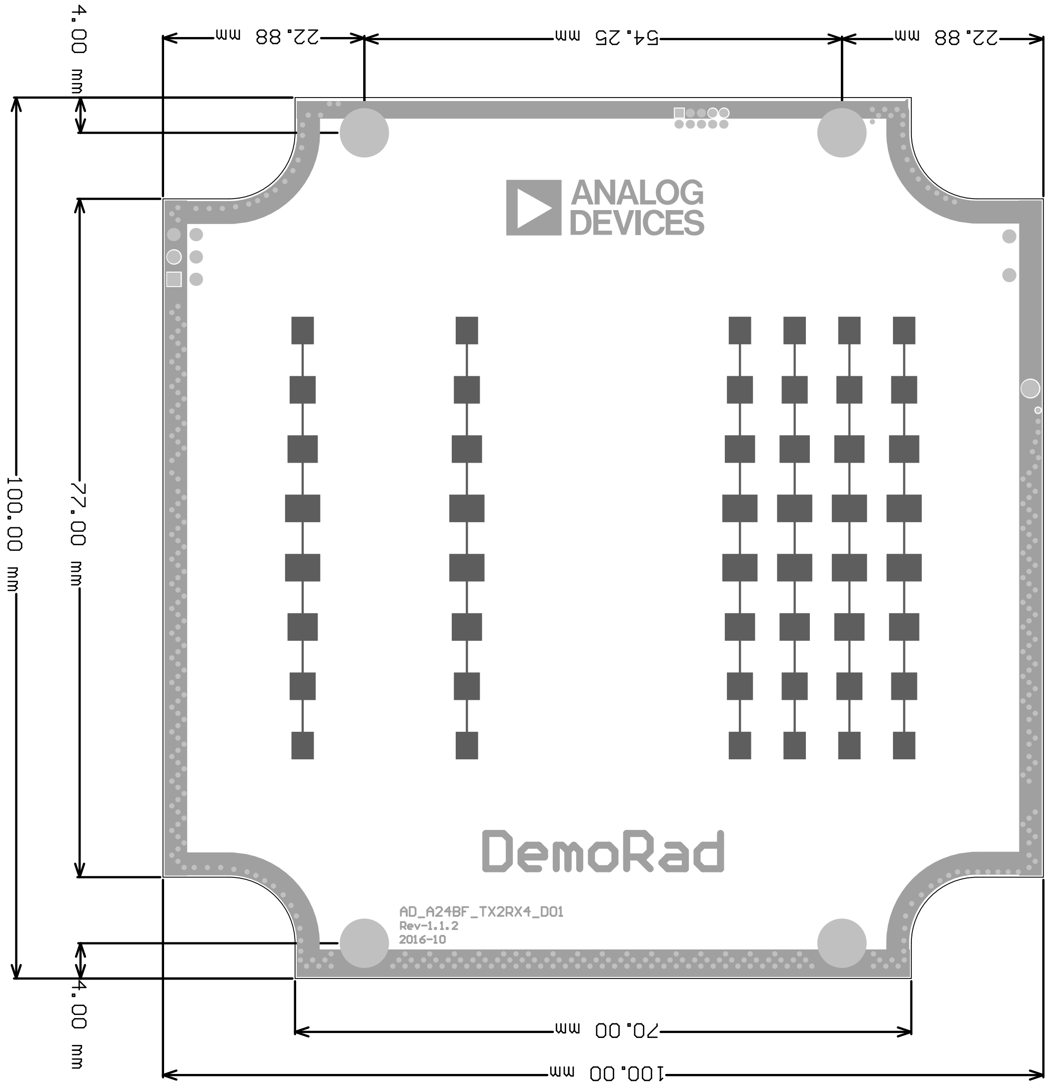

Figure 2: Dimensions of the 24-GHz radar system including the position of the mounting holes.

In Tab. 1 the mechanical parameters of the baord are summarized. The RF part and the digital part of the system are built on a six-layer PCB, where a Rogers RO-4350 is used as RF substrate.

Parameter	Value
Substrate	RO-4350
RF-Substrate thickness	0.25 mm
Dimension x-direction	100 mm
Dimension y-direction	100 mm
Weight frontend	60 g

Table 1: Mechanical parameters of the 24-GHz radar system.

3.2 Antenna Arrangement

In the following section the antenna system is described. The serial fed patch antennas feature eight elements with an amplitude taper and are fed from the backside of the PCB. The antennas are fabricated on a Rogers 4350 substrate. The resulting beam pattern for the E- and H-plane of the antenna is shown in Fig. 3. The sidelobe supression for the E-plane pattern is approximately 18 dB.

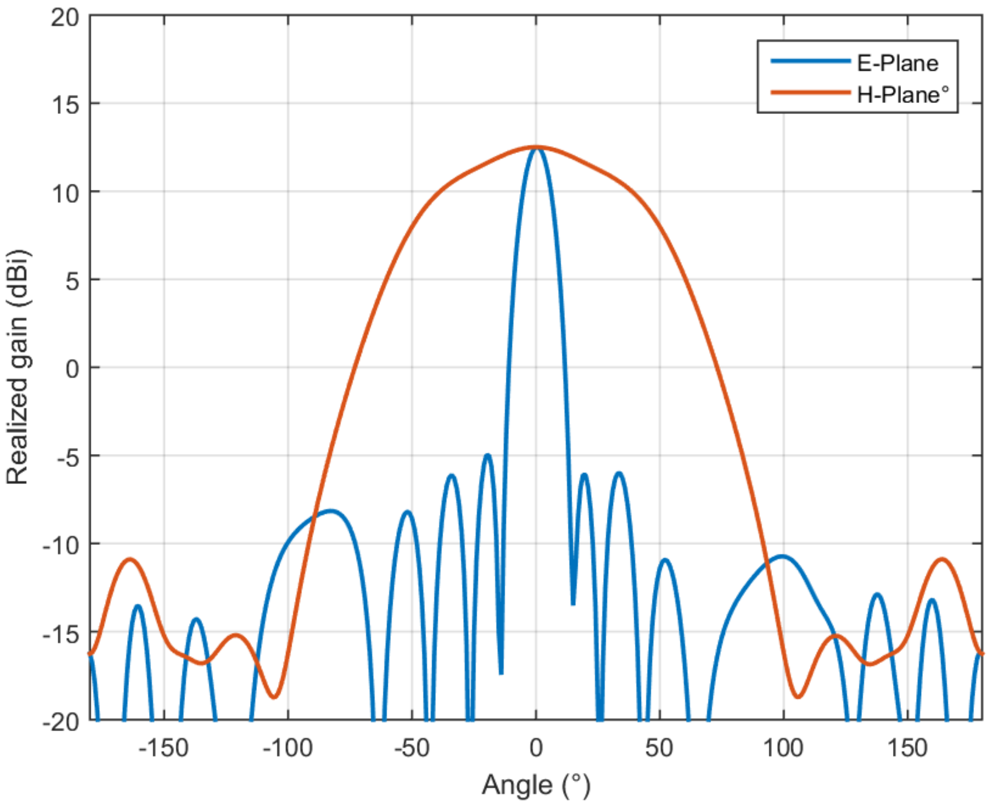

Figure 3: Realized gain of a single antenna.

In Tab. 2 the parameters of the antennas are summarized. The arrangement of the antennas is chosen to enable a virtual array with seven elements with a spacing of $\frac{\lambda_0}{2}$. Two elements overlap and

	Parameter	Value
G	Realized Gain	13.2 dBi
ΔS	Sidelobe suppression	-18 dB
Θ_{H}	Horizontal 3 dB beamwidth	76.5°
Θ_{V}	Vertical 3 dB beamwidth	12.8°

Table 2: Antenna parameters.

therefore can be used to implement motion compensation algorithms. In Fig. 4 the configuration of the virtual array is sketched. By subsequently switching between the transmit antennas the angular resolution can be increased. In Tab. 3.2 the x-positions fo the antennas are summarized,

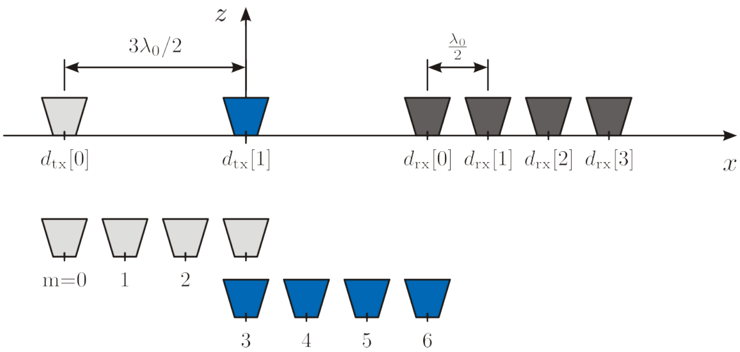

Figure 4: Antenna arrangement with virtual antenna positions.

where the second TX antenna is located in the origin of the coordinate system.

Antenna	x-Position
TX_1	-18.654 mm
TX_2	0.000 mm
RX_1	32.014 mm
RX_2	37.231 mm
RX_1	43.449 mm
RX_2	49.666 mm

3.3 Electrical Parameters

In Tab. 3 the electrical parameters of the frontend are specified. For a more detailed description of the electrical parameters refer to the data sheet of the transceivers (ADF5901 and ADF5904) from Analog Devices.

	Parameter	Condition	Min	Typ	Max	Unit
V_{Sup}	Supply Voltage	-	10.0	12.0	36	V
I_{C1}	Supply Current	@ 12.0 V / all RX enabled	-	-	290	mA
P_t	Max RF Output Power			8		dBm
	TX ON/OFF Isolation		-	30		dB
f_t	Transmit Frequency		23.9	-	24.3	GHz

Table 3: Electrical parameters of the 24-GHz radar system.

3.4 FMCW Measurements

In this section the results of FMCW performance measurements conducted in an anechoic measurement chamber are shown. In Tab. 4 the FMCW parameters used during the measurements are summarized. A corner cube with a radar cross-section of 0 dBSm was placed in a distance

Parameter	Description	Value	Unit
f_{Start}	Start frequency	23.9	GHz
f_{Stop}	Start frequency	24.3	GHz
T_{Ramp}	Upchirp duration	256	us
f_{s}	Sampling frequency	1	MHz
N	Number of samples for one chirp	256	
N_{p}	Number of chirps	128	

Table 4: FMCW parameters for the performance measurements.

of 5.06 m from the radar system. The results shown in this section can be used to estimate the performance of the radar system. In Fig. 5 the range profile is shown. To generate the range profile 128 measurements are averaged non-coherently. The green curve shows the expected amplitude for the corner cube with 0 dBSm and the chosen FMCW setup. The reflection of the corner cube can be seen in a distance of 5.10 m. At a distances of one meter behind the corner cube the reflections from the walls of the measurement chamber are observed. At range bins greater 10 m no reflections are present and the noise floor of the system can be extracted.

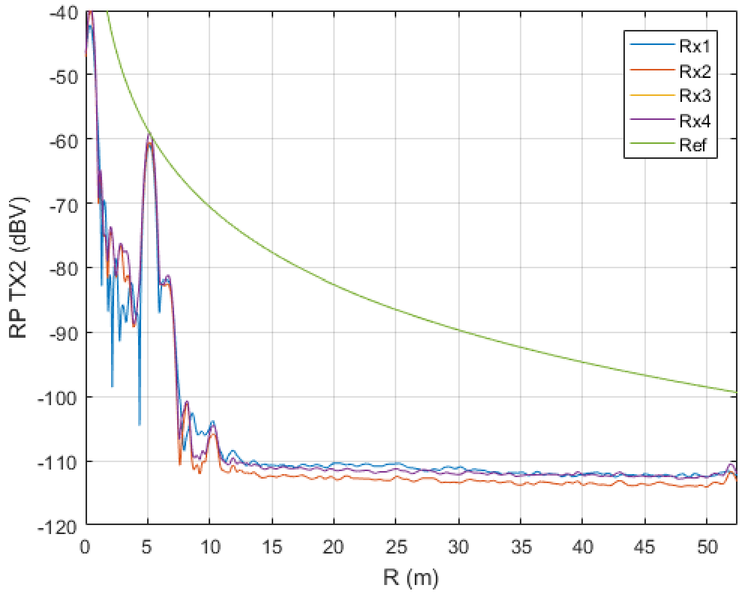

Figure 5: Averaged range profiles for the corner cube in the measurement chamber.

The reference curve in conjunction with the noise floor of the system can be used to estimate the maximum distance at which the corner cube can be detected for the given FMCW parameters.

In a distance of 50 m the spectral SNR is approximately 14 dB.

In the next step a range-Doppler map is evaluated, where the $N_p = 128$ chirps are processed coherently. In Fig. 6 the range-Doppler map of the stationary corner cube is plotted. The velocity

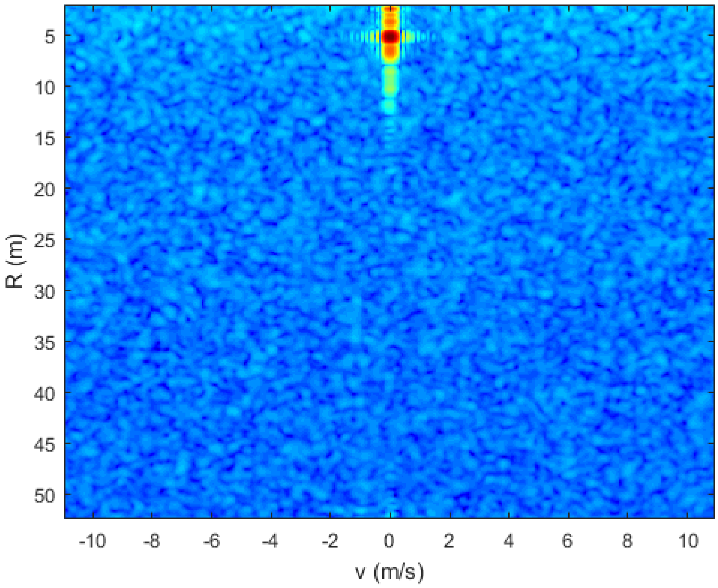

Figure 6: Averaged range-Doppler map for the corner cube in the measurement chamber.

profile for the given scene is shown in Fig. 7. It can be observed that the spectral SNR is increased due to the coherent processing of the chirps.

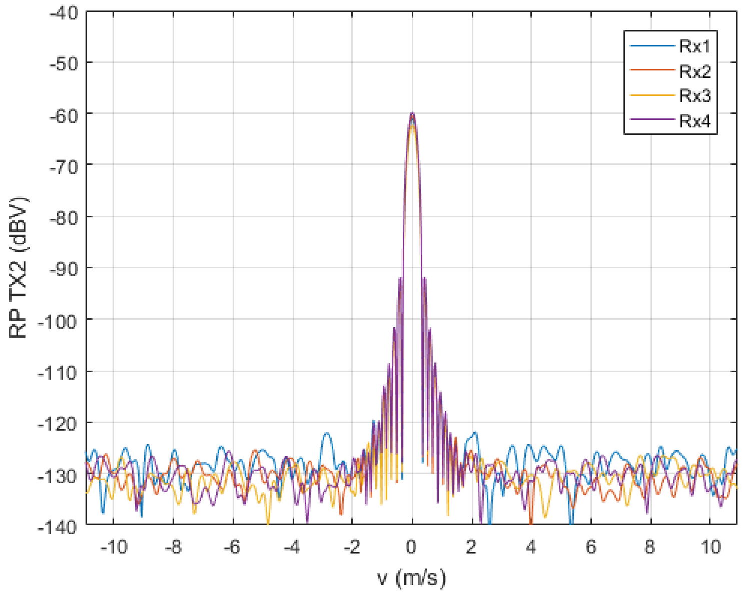

Figure 7: Averaged velocity spectrum at the position of the corner cube.

3.5 FMCW Timing

The FMCW timing of the DemoRad is fixed and can not be altered within the current software framework. The ramp configuration consits of continuous up- and downramps as shown in Fig. 8. The start and stop frequencies of the FMCW signal can be configured before starting the measurements. For instance the graphical user interface can be used to alter the bandwidth of the FMCW waveform. The duration of the upchirp is set to $T_{\mathrm{Up}} = 280\,\mu s$ and the duration of the downchirp

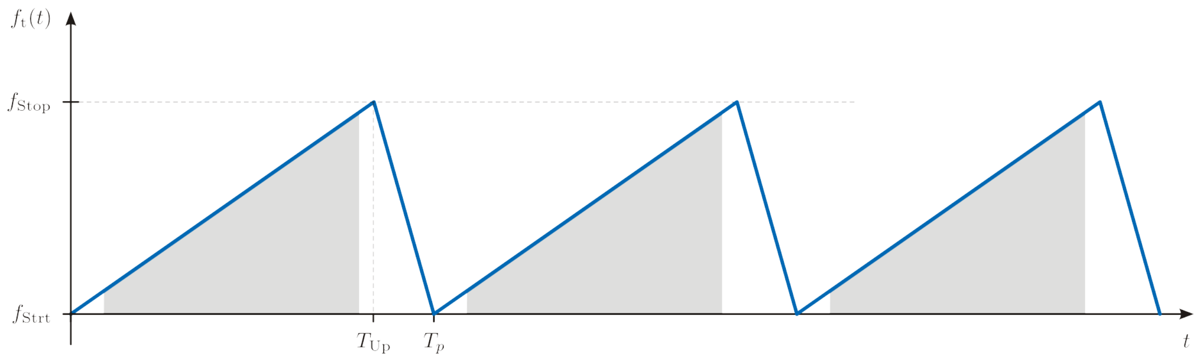

Figure 8: Ramp configuration with continuous up- and downchirps.

is $4\,\mu s$. This setup corresponds to a chirp repetition interval of $T_{\mathrm{p}} = 284\,\mu s$. The gray scaled part during the upchirps shows the interval, where the sampling of the IF signals take place. For every upchirp 256 samples are recoreded with a fixed sampling frequency of $f_{\mathrm{s}} = 1$ MHz. Therefore, the sampled or effective ramp duration is $256\,\mu s$. In addition, the sampled bandwidth is also reduced.

The DSP framework collects 128 adjacent frames, which can be accessed from the USB 2.0 interface. If the DSP receives a sampling command form the host computer then 128 upchirps are collected and returned to the computer. Hence the timing depends on the speed of the host computer.