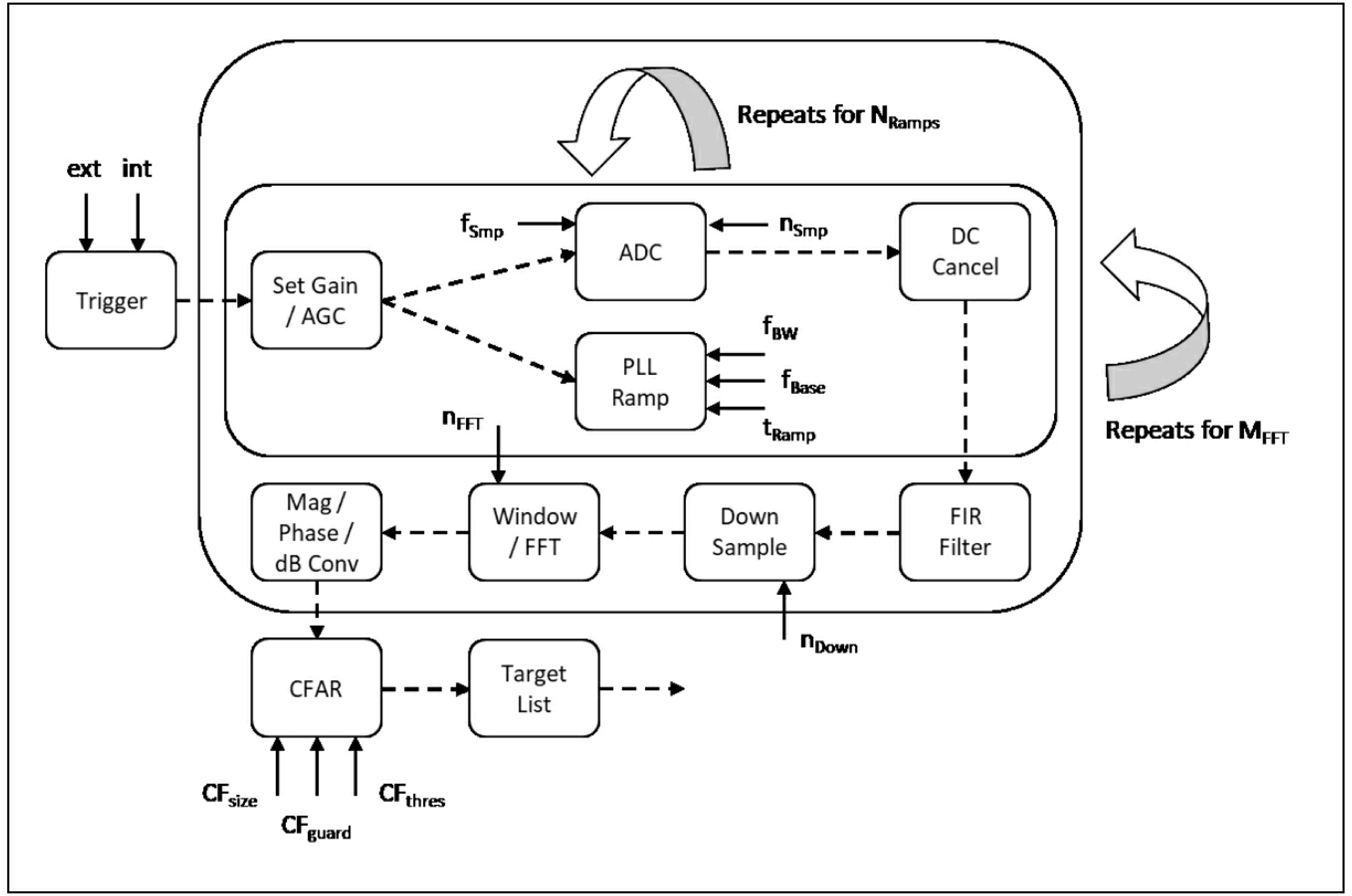
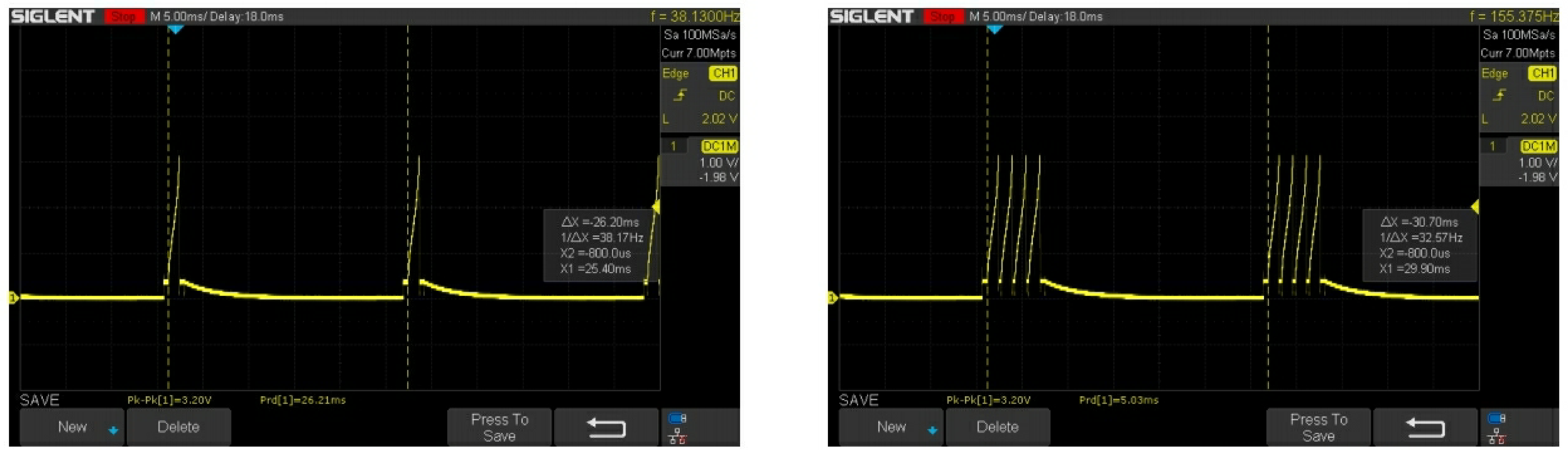
Architettura generale del sistema



If the Self-Trigger Mode is switched on (default), the device sends a ramp group for each measurement, also shown in Figure 3. The number of ramps can be adjusted and also set to single ramps as shown in Figure 3 (left). The time between the ramp groups or single ramps is time needed for processing and data output and varies with the chosen processing settings. The time can be minimized by switching off unnecessary data output and choosing less complex computation and measurement settings. Figure 3 shows the ramping with AGC Mode switched off.



Single Ramps | Ramp Groups of 4 Ramps Each

Figure 3 Single Ramp vs. Ramp Group

Struttura della segnalazione verso la board

3.1 Command Frames

Each command frame starts with ASCII value 33 ('!') as start marker and ends with two ASCII command characters ('CR' and 'LF') as stop marker, also see the blue parts in Figure 9. Orange parts indicate data parts (explained later in this section).

Command frames

Configuration command	Start	Identifier	Command settings (8 Digits)	Stop	
System configuration	!	S	SYS_CONFIG	CR	LF
Radar frontend config.		F	RFE_CONFIG		
PLL configuration		P	PLL_CONFIG		
Baseband configuration		B	BB_CONFIG		
Programming mode		W	ProgMode (fixed)		

Short command	Start	Identifier	Stop	
Get full error report	!	E	CR	LF
Get system info		I		
Do frequency scan		J		
Set to max. bandwidth		K		
Send Pre-Trigger		L		
Send Trigger		M		
Send both Triggers (L, M)		N		
Get version info		V		

!	Start Marker, Identifier and Stop Marker	
x	Hex Digit	[0,1,2,...,A,B,C,D,E,F]
c	Ascii Character	[decimal 34 .. 255]

3.3 Configuration (Long) Commands

The commands in Table 9 contain data for the configuration of the kit and are explained in the following sections. The configuration commands are available in all output modes.

Table 9 Configuration Commands

Command Frame	Identifier	Answer	Description
System configuration	S	X	Configure basic functions of the system
Radar front end configuration	F	X	Configure front end base-frequency
PLL configuration	P	X	Configure the bandwidth of the frequency ramp
Baseband configuration	B	X	Configure baseband and processing related parameters
Programming mode	W	-	Used to flash SiRad Simple® without hardware configuration

3.3.1 System Configuration

The system configuration command configures basic functions of the system, including triggering, LED, data output, and gain. When the ERR, ST, TL, P, C, R, CPL, or RAW bits are enabled, the according frame will be output after each measurement. Use these bits to switch the transmission of these frames on or off. Switching unnecessary frames off can increase the update rate of the device significantly.

Please note that, if the wrong SER connection option is selected, there will be no data displayed on the selected platform. However, *SiRad Easy®* and *SiRad Simple®* always listen on both serial ports, so reconfiguring is possible at any time.

Bit	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
SYS_CONFIG	SelfTrigDelay			res	LOG	FMT	LED		reserved				Protocol			AGC	Gain		SER2	SER1	ERR	ST	TL	C	R	P	CPL	RAW	res	res	SLF	PRE

SelfTrigDelay			
0	0	0	0 ms
0	0	1	2 ms
0	1	0	4 ms
0	1	1	8 ms
1	0	0	16 ms
1	0	1	32 ms
1	1	0	64 ms
1	1	1	128 ms

LED		
0	0	off
0	1	1st target
1	0	reserved
1	1	reserved

Gain		
0	0	8 dB
0	1	21 dB
1	0	43 dB
1	1	56 dB

SER2	
0	output on SER2 off
1	output on SER2 on

SER1	
0	output on SER1 off
1	output on SER1 on

FMT	
0	TL mm distance
1	TL cm distance

LOG	
0	log MAG
1	linear MAG

data frames		off	on
RAW	raw ADC	0	1
CPL	cmplx FFT	0	1
P	phase	0	1
R	magnitude	0	1
C	CFAR	0	1
TL	target list	0	1
ST	status	0	1
ERR	error	0	1

Protocol			
0	0	0	WebGUI
0	0	1	TSV output
0	1	0	BIN output
x	x	x	reserved

SLF	
0	external trig mode
1	standard mode

PRE	
0	standard mode
1	use pre-trigger

AGC	
0	auto gain control off
1	auto gain control on

Figure 10 System Configuration Frame Format

SYS_CONFIG	SelfTrigDelay	res	LOG	FMT	LED	reserved	Protocol	AGC	Gain	SER2	SER1	ERR	ST	TL	C	R	P	CPL	RAW	res	res	SLF	PRE
EASY	0	0	0	0	1	0	0	1	0	1	0	1	1	1	1	1	0	0	0	0	0	1	0
SIMPLE	0	0	0	0	1	0	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0

Figure 11 System Configuration Default Bit Settings

Table 11 System Configuration Bits

Format Field	Field Size	Description
SelfTrigDelay	3 bits	Sets a delay time between self-trigger events
LOG	1 bit	Sets scaling type of magnitude data; when set to 0, magnitude data is in dB; **linear scaled magnitude outputs are ONLY useful for TSV or binary output format**
FMT	1 bit	Select the data output format: mm / cm
LED	2 bits	When set to 1st target rainbow, the LED displays the distance of the first recognized target as a color from blue (far) over green (medium range) to red (close). The current maximum range is used as a reference.
Protocol	3 bits	Protocol type for data output: WebGUI, TSV (tab separated values) and binary; **TSV and binary outputs are NOT displayed in the WebGUI**
AGC	1 bit	Auto Gain Control mode: overrides the manual settings in the 'Gain' field. Uses 2 ramps at the beginning of the measurement or the pre-trigger phase for gain measurement (depending on whether 'Pre-trigger' is switched on).
Gain	2 bits	Manual gain setting. Overridden by the AGC bit, which enables Auto Gain Control.
SER1	1 bit	UART-USB connection on the Simple, WIFI or header bar on the SiRad Easy®
SER2	1 bit	USB connection on SiRad Easy®; configuration data can be fed to the device using both UARTs at any time
ERR	1 bit	Enables the Error Information frame
ST	1 bit	Enables the Status Information frame
TL	1 bit	Enables the Target List frame
P	1 bit	Enables the Phase frame
C	1 bit	Enables the CFAR frame
R	1 bit	Enables the Magnitude / Range frame
CPL	1 bit	Enables the Complex FFT data frame; **NOT displayed in the WebGUI**
RAW	1 bit	Enables the ADC raw data (I/Q) frame; **NOT displayed in the WebGUI**
PRE	1 bit	Enable pre-trigger (applies only in manual trigger mode)
SLF	1 bit	Switch between self-trigger and manual trigger

3.3.3 PLL Configuration

The PLL configuration command sets the bandwidth for the radar front end. The bandwidth can be configured in 2 MHz steps. A negative bandwidth can be set as well, the charge pump output of the PLL will be inverted.

IMPORTANT:
The radar front ends are able to use a larger bandwidth than what is allowed in the ISM bands. In most countries, the bandwidth is limited to 1 GHz between 122 GHz and 123 GHz for production purposes by law. Please check your local regulations. It remains the customer's responsibility to assure the operation of the front end according to local regulations, especially applying to frequency band allocations outside of the laboratory environment. Silicon Radar and its distributors will not accept any responsibility for consequences resulting from the disregard of these instructions and warnings.

Bit	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
PLL_CONFIG	reserved																Bandwidth [MHz] (16 Bits)															

Bandwidth [MHz] (16 Bits)																
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-2 MHz
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	-4 MHz
...																
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-65536 MHz
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 MHz
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2 MHz
...																...
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	+65534 MHz

Figure 14 PLL Configuration Frame Format

PLL_CONFIG	reserved																Bandwidth [MHz] (16 Bits)															
EASY 120 GHz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	1	0	0
EASY 24 GHz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0
SIMPLE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	1	0	0

Figure 15 PLL Configuration Default Bit Settings

3.3.4 Baseband Configuration

The baseband configuration command configures baseband and processing related parameters: sampling parameters, DC cancellation, windowing, down sampling, FIR Filter, FFT parameters, and CFAR parameters.

Bit	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
BB_CONFIG	WIN	FIR	DC	CFAR		CFAR Threshold [dB]				CFAR Size				CFAR Grd		Average n		FFT Size			Down sample			# Ramps			# Samples			ADC ClkDiv		

WIN	
0	windowing off
1	windowing on

FIR	
0	FIR filter off
1	FIR filter on

DC	
0	DC cancellation off
1	DC cancellation on

FFT Size			
0	0	0	32
0	0	1	64
0	1	0	128
0	1	1	256
1	0	0	512
1	0	1	1024
1	1	0	2048
1	1	1	reserved

Down sample			
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	4
1	0	0	8
1	0	1	16
1	1	0	32
1	1	1	64

# Ramps			
0	0	0	1
0	0	1	2
0	1	0	4
0	1	1	8
1	0	0	16
1	0	1	32
1	1	0	64
1	1	1	128

# Samples			
0	0	0	32
0	0	1	64
0	1	0	128
0	1	1	256
1	0	0	512
1	0	1	1024
1	1	0	2048
1	1	1	reserved

ADC ClkDiv			MS/s
0	0	0	2,571
0	0	1	2,400
0	1	0	2,118
0	1	1	1,800
1	0	0	1,125
1	0	1	0,487
1	1	0	0,186
1	1	1	0,059

CFAR		
0	0	CA-CFAR
0	1	CFAR_GO
1	0	CFAR_SO
1	1	reserved

CFAR Threshold [dB]				dB
0	0	0	0	0
0	0	0	1	2
				...
1	1	1	1	30

CFAR Size				
0	0	0	0	0
0	0	0	1	1
...				
1	1	1	1	15

CFAR Grd		
0	0	0
0	1	1
1	0	2
1	1	3

Average n		
0	0	0
0	1	1
1	0	2
1	1	3

Figure 16 Baseband Setup Frame Format

Bit	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
BB_CONFIG	WIN	FIR	DC	CFAR		CFAR Threshold [dB]				CFAR Size				CFAR Grd		Average n		FFT Size			Down sample			# Ramps			# Samples			ADC ClkDiv		
EASY&SIMPLE	1	0	1	0	0	0	1	0	0	1	0	1	0	0	1	0	1	1	0	0	0	0	0	1	0	0	1	0	0	1	0	1

Figure 17 Baseband Setup Default Bit Settings

Table 18 Baseband Setup Bits

Format Field	Field Size	Description
WIN	1 bit	Enables Windowing on the samples before performing the FFT
FIR	1 bit	Enables the FIR filter
DC	1 bit	Enables digital de-trending and static offset compensation
CFAR	2 bits	Select the CFAR operator
CFAR Threshold	4 bits	CFAR threshold value added to average of the CFAR operator; value range is 0 to 30 in step size of 2
CFAR Size	4 bits	Number of cells left and right of the CFAR guard interval; value range is 0 to 15
CFAR Guard	2 bits	Number of guard cells left and right of the cell under test; value range is 0 to 3
Average n	2 bits	Selects how many FFTs are averaged
FFT Size	3 bits	Number of FFT points
Down Sample	3 bits	Down sampling factor
#Ramps	3 bits	Number of ramps used for each measurement
#Samples	3 bits	Number of samples used for each measurement
ADC ClkDiv	3 bits	Select the sampling frequency

Ramp time: The ramp time t is calculated using the selected sampling time t_{Smp}, the number of samples n_{Smp} and the clock frequency of the ADCs according to Table 19, like

Equation 1 Ramp Time

$$t\,[us] = t_{Smp}\,[\text{clock cycles}] * (n_{Smp} + 85) / (36\,\text{MHz})$$

Accuracy: the width of one distance bin of the sensor after the formula

Equation 2 Accuracy

$$acc = c * (nSmp + 85) / (2 * BW * nFFT * 2ndown)$$

where *c* is the speed of light, *BW* is the bandwidth, n_{Smp} is the number of samples, n_{FFT} is the FFT size, and n_{down} is the downsampling factor.

Downsampling: determines how many samples are averaged after sampling. Higher downsampling values improve the accuracy but reduce the maximum range. Voids are filled with zeroes when downsampling. A downsampling of 0 means no downsampling, 1 means an average of 2 values, 2 an average of 4 values, etc.

Segnalazione in uscita dalla board

TSV format

Sensor data	Start	Identifier	Delim	Counter	Del	Size	Del	SGN	Data	Del	Stop	
								Size Blocks --->				
FFT/Magnitude/Range frame	!	R	/t	n	/t	n	/t	-	n	/t	CR	LF
Phase frame	!	P										
CFAR frame	!	C										
Raw Frame	!	M										

!	Start Marker, Identifier and Stop Marker	
x	Hex Digit	[0,1,2,...,A,B,C,D,E,F]
c	Ascii Character	[decimal 34 .. 255]
c	Ascii Character	any char value
n	String Number	any length

Target information	Start	Identifier	Del	Counter	Del	Format	Del	Gain	Del	Target #	Del	Distance	Del	SGN	Mag	Del	SGN	Phase	Del	res.	Del	Stop	
										Block, repeated 16 times --->													
Target list frame	!	T	/t	n	/t	n	/t	c	/t	n	/t	n	/t	-	n	/t	-	n	/t	n	/t	CR	LF

Status update frame	Start	Identifier	Del	Counter	Del	Format	Del	Gain	Del	Accuracy	Del	Max. range	Del	Ramp time	Del	SGN	Bandwidth	Del	Time diff.	Del	Stop	
Status update frame	!	U	/t	n	/t	n	/t	c	/t	n	/t	n	/t	n	/t	-	n	/t	n	/t	CR	LF

The size of the ADC raw data output is always 2 * "Number of Samples" when no down sampling is configured.

Sensor data	Start	Identifier	Delim	Counter	Del	Size	Del	SGN	Data	Del	Stop	
								Size Blocks --->				
FFT/Magnitude/Range frame	!	R	/t	n	/t	n	/t	-	n	/t	CR	LF
Phase frame	!	P										
CFAR frame	!	C										
Raw Frame	!	M										

Figure 31 TSV ADC Raw Data, Magnitude, Phase and CFAR Data Frame Format

Table 29 TSV ADC Raw Data, Magnitude, Phase and CFAR Data Bits

Format Field	Content	Encoding
Del	Delimiter	\t
Counter	Measurement cycle counter	decimal between 0 to 65535
Size	Size of the transmitted data	decimal between 0 to 65535
Sgn	Sign indicator	
Data	FFT/Magnitude/Range/Phase/CFAR/ Raw Data	decimal between -32768 to +32767

5.3 Status Update

In the TSV status update frame, the unit for the maximum range is mm, for the ramp time us, and for the bandwidth MHz. To be able to convert accuracy filed into mm, the data should be divided by 10. If the accuracy field says 271, the system accuracy yields to 27.1 mm. The frame counter is a 16 bit number starting from 0 and increasing by 1 with each measurement cycle. The frame counter automatically overflows to 0 after reaching the maximum value 65535.

Status update frame	Start	Identifier	Del	Counter	Del	Format	Del	Gain	Del	Accuracy	Del	Max. range	Del	Ramp time	Del	SGN	Bandwidth	Del	Time diff.	Del	Stop	
Status update frame	!	U	/t	n	/t	n	/t	c	/t	n	/t	n	/t	n	/t	-	n	/t	n	/t	CR	LF

Figure 33 TSV Status Update Data Frame Format

Table 32 TSV Status Update Data Bits

Format Field	Content	Encoding
Del	Delimiter	\t
Cnt	Measurement cycle counter	decimal between 0 to 65535
Format	Indicates the distance unit	decimal between 0-1
Gain	Indicates the current gain level	decimal 8,21,43 or 56
Accuracy	Device accuracy	decimal between 0 to 65535
Max. range	Maximum range of device	decimal between 0 to 65535
Ramp time	Length of the ramp in us	decimal between 0 to 65535
Bandwidth	Bandwidth in MHz	decimal between-32768 to +32767, Interpretation = -65536 to 65534 in MHz (2 MHz steps)
Time difference	Indictor for update rate	decimal between 0 to 65535

Binary output

Sensor data	Header	Chn	Counter	Length	Data (Length * 2 Bytes)	Stop	
ADC data	$AA $AA $BB $CC	M	2 Bytes uint16	Size n uint16	int16	CR	LF
Range/FFT/Mag		R			int16		
Phase frame		P			int16		
CFAR frame		C			int16		

Status Info	Header	Chn	Counter	Format	Gain	Accuracy	Ramp Time	Max. Range	Real Bandwidth	Time Diff	Stop	
System Update	$AA $AA $BB $CC	U	uint16	uint8	uint8	2 Bytes uint16	uint16	uint16	int16	uint16	CR	LF

Error Info	Header	Chn	Counter	Error Flags	Stop	
Error frame	$AA $AA $BB $CC	E	uint16	uint8	CR	LF

Target Informantion	Header	Chn	Counter	Format	Gain	Target #	Distance	Magnitude	Phase	Reserved int16	Stop	
						Block, repeated 16 times --->						
Target List frame	$AA $AA $BB $CC	T	uint16	uint8	uint8	uint8	uint16	int16	int16		CR	LF

Header
Delimiter
binary Data

Figure 35 Binary Data Frames

6.1 ADC Raw Data (I/Q), Magnitude, Phase and CFAR Output

The binary frame starts with a header and channel indicator, followed by a frame counter. The frame counter is a 16 bit number starting from 0 and increasing by 1 with each measurement cycle. The frame counter automatically overflows to 0 after reaching the maximum value 65535. The value range of the ADC raw data for 1 ramp is 12 bits (0 to 4096).

Sensor data	Header	Chn	Counter	Length	Data (Length * 2 Bytes)	Stop	
ADC data	$AA $AA $BB $CC	M	2 Bytes uint16	Size n uint16	int16	CR	LF
Range/FFT/Mag		R			int16		
Phase frame		P			int16		
CFAR frame		C			int16		

Figure 36 Binary Range, Phase and CFAR Data Frame Format

Table 33 Binary Range, Phase and CFAR Data Bits

Format Field	Field Size	Content	Encoding	Allowed Values
Header		Start of frame	Fixed	Fixed
Identifier	1 byte	Frame identifier	Fixed	Fixed
Counter	2 bytes	Measurement cycle counter	Unsigned Integer	decimal between 0 to 65535
Length	2 bytes	Size of the transmitted data	Unsigned Integer	decimal between 0 to 65535
Data	Length * 2 bytes	Magnitude/Range/Phase/CFAR/ADC	Signed Integer	decimal between -32768 to +32767

6.3 Status Update

In the binary status update frame, the unit for the maximum range is mm, for the ramp time us, and for the bandwidth MHz. To be able to convert accuracy filed into mm, the data should be divided by 10. If the accuracy field says 271, the system accuracy yields to 27.1 mm. The frame counter is a 16 bit number starting from 0 and increasing by 1 with each measurement cycle. The frame counter automatically overflows to 0 after reaching the maximum value 65535.

Status Info	Header	Chn	Counter	Format	Gain	Accuracy	Ramp Time	Max. Range	Real Bandwidth	Time Diff	Stop	
System Update	$AA $AA $BB $CC	U	uint16	uint8	uint8	2 Bytes uint16	uint16	uint16	int16	uint16	CR	LF

Figure 38 Binary Status Update Data Frame Format

Table 36 Binary Status Update Data Bits

Format Field	Field Size	Content	Encoding	Allowed Values
Header		Start of frame	Fixed	Fixed
Identifier	1 byte	Frame identifier	Fixed	Fixed
Counter	2 bytes	Measurement cycle counter	Unsigned Integer	0 to 65535
Format	1 byte	Indicates the distance unit	Unsigned Integer	0 to 1
Gain	1 byte	Indicates the current gain level	Unsigned Integer	8, 21, 43 or 56
Accuracy	2 bytes	Device accuracy	Unsigned Integer	0 to 65535
Ramp time	2 bytes	Maximum range of device	Unsigned Integer	0 to 65535
Max. Range	2 bytes	Length of the ramp in us	Unsigned Integer	0 to 65535
Bandwidth	2 bytes	Bandwidth in MHz	Signed Integer	-32768 to +32767, Interpretation = -65536 to 65534 in MHz (2 MHz steps)
Time diff.	2 bytes	Indictor for update rate	Unsigned Integer	0 to 65535

Table 37 Binary Status Update Data - Format Field

Format (HEX)	Description
0	distance in mm
1	distance in cm

Consigli generali

How to increase SNR

- Increase number of ramps
- Setting a higher gain

How to increase update rate

There are several steps that you can follow to increase the update rate. Please see the protocol description[1] for detailed information.

- **AGC mode disable:**

When AGC mode is selected, the kit drives 2 additional ramps in order to determine the suitable gain settings according to the environment.

- **Reduce the data transmission time:**

Disabling the data frames that you do not need will result in lower transmission time.
Secondly, you might also decrease the transmitted data length (FFT size or number of samples).
Select only one of SER. Therefore the evaluation kit will transfer the data through only one SER.
Activate Binary protocol, due to less size of transmitted data the update rate will increase

- **Reduce the number of ramps**

Reducing the number of ramps decreases the time or ramping. Reducing the number of ramp affects SNR, you might need to adjust according to your application.

- **Reduce the ADC Clk Divider**

Smaller ADC Clk divider settings results higher sampling frequencies and therefore shorter sampling time.

- **Assign 0 to Self Trigger delay**
- **Disable unnecessary processing**

In order to shorten processing time, unnecessary processing steps can be disabled. Switching off processing steps will depend on your application.
Secondly, reducing the FFT size results shorter processing time however smaller FFT size causes lower accuracy.
Reducing number of samples results shorter measurement time and shorter processing time. However changing number of samples affects accuracy and maximum range of the system.

How to increase accuracy

- **Increase FFT size**

Increasing FFT size increases the accuracy however, lowers the update rate.

- **Decrease number of samples**

Decreasing the number of samples increases the accuracy however, lowers the maximum range.

- **Enable downsampling**
- **Increase bandwidth**

Guida setup RAW output

2.1 Raw ADC

To acquire raw ADC data from the kit you need to follow the steps below:

System Configuration Command:

- set 1 to RAW bit

After that you need to de-select processing-related parameters, otherwise, you will receive ADC data with selected processing applied. Secondly, the value range of the raw ADC data for 1 ramp is 12 bits (0 to 4096), the number of ramps should be less than 16 to eliminate saturation.

Baseband Configuration Command:

- set 0 to WIN bit
- set 0 to FIR bit
- set 0 to DC bit
- Adjust Number of ramps

WebGUI does not support ADC data demonstration!

Change the data format from WebGUI:

- Open the Com2WebSocket tool, select the correct baud rate and COM port for your firmware, and connect to the system
- Open the WebGUI and connect to the WebSocket provided by the Com2WebSocket tool
- (Optional) Set any desired RF, processing, and target recognition parameters
- Change to the “Output Data” tab
- Chose the protocol type with the “Protocol Type” slider
- Select the desired output data checkboxes