
MANUAL FOR THE RADAR MODULE IN PUCK RADAR

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INTRODUCTION

This document describes how to start and configure the radar module in the Puck Radar device.

Please note that increases of number of Hardware Accelerated Average Samples (HWAAS) as well as average sweep and higher frequency of measurements and longer distance, will all effect power consumption and shorten the battery life time.

CONFIGURATION

The commands & settings are applied using a mobile app or OTA over LoRaWAN.

Commands

To communicate with device radar unit, use the commands in the table. The use of the commands is explained below.

Command	Parameters	Description
version		Returns current radar module firmware version
factory		Resets all radar module settings to factory default
mac		Returns the radar module mac address
restart		Restarts the radar module
sys:?		Returns the system parameters, see section 4
sys:[params]	see section 3.1	Sets system parameters
x:?		Returns the Method parameters, see section 4
x:[params]	see section 3.1	Sets one or several settings for Method x

Settings

The position in the settings string determines which parameter the value belongs to.

There are two categories of parameters, generic parameters related to the **system** (sys), e.g.

- Selection of Method
- Bluetooth parameters
- Enabling the radar
- Etc

and parameters related to a selected Method (e.g. method 5 for parking), e.g.

- Measurement cycle
- Range
- Sensitivity level
- Etc.

For detailed information see section 3.1 System and Method parameters

Example. Activate and deactivate the Radar

It is possible to change a single parameter by omitting all parameters except the one to change as in this example to activate the sensor scan:

Activate

sys:,,,,,1

Deactivate

sys:,,,,,0

Method settings

The settings for different Methods can vary but the current settings can always be shown by using the “:?” option.

Response

All commands will return a string in which the first position indicates whether the operation was successful or not. A '=' means success and '*' means error.

Example

sys:3

sys:5,250,5,0,8,0

3:60

The first command will activate method 3. The second command will update all system parameters. The third command will change the measurement cycle for method 3 to 60 seconds.

METHODS

1: Distance method

This is a generic distance measurement method with the same common configuration parameters as in the following methods but with some extra possibilities to select the closest, strongest or most distant object detected by the radar. When the strongest reflection is considered, there are the option to compensate for the decrease of signal strength dependent on the distance and the shape of the object, i.e. round or flat.

3: Well method

The method will return the echo (distance and amplitude) at the largest distance within

the measurement range and above the sensitivity level. Well suited for applications where it could be assumed that the echo at the largest distance is the correct object to measure. Any echo at closer distance will be neglected.

Examples of applications suited for the well method includes:

- Wells
- Septic tanks
- Snow level (Snow level = Distance to ground – Distance to snow)
- Water level (Water level = Reference ground level – Distance to water)

The method may return false values if the dominating radar echo originates from an unintended radar path such:

1. Radar reflections in the sidewall.
2. Radar echoes reflected in the sensor, the sensor mounting or any lid/construction above the sensor.
3. Radar echoes from the actual bottom of the well.

See picture 1 below.

Determine carefully the mounting position and range of your measurement to minimize the occurrence of false echoes. E.g.

- “Length of Range” < Distance from Puck Radar to the bottom of the well - 10 cm.
- Distance to the highest possible water level in the well should preferably be larger then $(\text{“Start of Range”} + \text{“Length of Range”})/2$
- Position the device to avoid reflections in the side walls as in the left picture below.
- Pay attention to the environment around and above the device to minimize that the radar is reflected and bounces back. Avoid large reflective materials (metal etc).

In most cases, Puck Radar with the narrow lens will perform better for these applications.

A radar beam forming lid with a round aperture can be purchased from Sensative to further the width of the radar beam and used with the Puck Radar narrow lens.

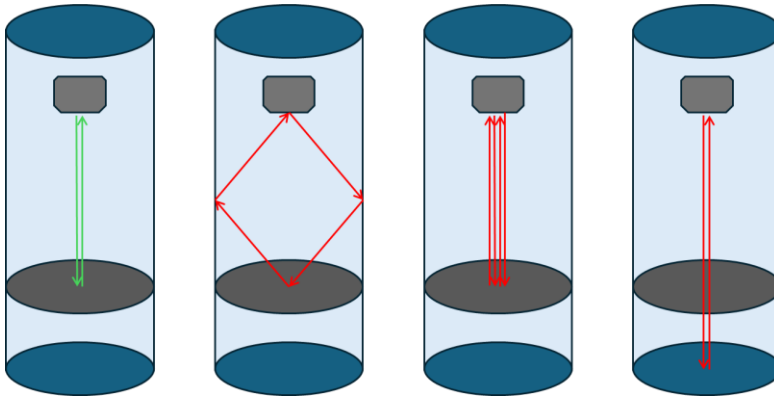


Figure 1. Radar paths. Green shows the radar path to correctly measure the distance to the water level. Green shows the radar path to correctly measure the distance to the water level while the others show side reflections, double bounces and reflections of the bottom.

4: Bin method

The bin method will return the amplitude of the radar signal echo and the distance to the closest object with a radar echo amplitude above the threshold level. The method is well suited for detecting when it is time to empty a waste bin.

Puck Radar with a narrow lens is usually more suitable for bin applications.

Note that this method is very sensitive to echoes from any close objects. Very small echoes can be handled by increasing the threshold level. Random echoes in the near proximity like raindrops can be filtered out by increasing the average factor.

The sensor could be mounted above the waste bin to detect when it is full by measuring the distance to the nearest object with a reflection amplitude above the threshold level.

The sensor could also be mounted on one of the side walls of the container such that the radar signal is directed across the container top segment and objects in the container will reflect the radar signal when they reach the level of that top segment. A radar beam forming lid with a horizontal aperture can be purchased from Sensative to create a wide, but thin, radar beam detecting any waste object reaching the top of the waste bin with a better precision.

5: Parking method

The parking method will detect the largest radar signal echo within the defined measurement range and above the defined threshold. The method is well suited for detecting the presence of a large object such as a vehicle in a well-defined area. Normal or narrow lens should be selected based on the width of the area to cover. The beam forming lid could be used to further narrow the area to monitor.

6: Seating method

The seating method will return the distance and amplitude at the largest radar signal echo within the defined measurement range and above the defined threshold. The method also reports if the seat is considered occupied or free. The state of occupied changes from occupied to free and vice versa, when a configurable number of consecutive measurements show the same result. The number of consecutive measurements is configurable separately for each direction.

Puck Radar with narrow lens is usually most suitable for seating applications.

The detection works best in a setup where obstacles around the seat are defined, e.g. cars, buses and trains. Mount the Puck sensor and finetune the distance and threshold to get a firm detection in a representative seat. Adjust the parameter value to switch between occupied and free seats, to filter out temporary events and further improve the reliability of the measurement.

FUNCTIONS

The algorithms both detect the presence of objects and estimate their distance to the radar.

RADAR RANGE

Puck's can detect objects between 0.2 to 6.8 m from the device. However, the actual range will vary depending on the structure and material of the object as the reflection index and angle of the reflection will affect how much of the radar energy that is received back to the sensor.

Note the actual range is effected by the CFAR-window parameter if the threshold method CFAR is used.

HWAAS

HWAAS (HW Accelerated Average Samples), number of samples taken to obtain a single point in the data. These are averaged directly in the sensor hardware - no extra computations are done in the CPU.

The time needed to measure a sweep is roughly proportional to the HWAAS. Hence, if there's a need to obtain a higher sweep rate, HWAAS could be decreased. Note that HWAAS does not affect the amount of data transmitted from the sensor.

HWAAS must be at least 1 and not greater than 63.

AVERAGE

To decrease the effect of noise, and increase the signal quality, multiple sweeps can be averaged. Collecting sweeps takes time and consumes power, so the optimal number of sweeps collected for averaging is use-case dependent.

MEDIAN

To get better precision in distance value a median algorithm with a delay option may be applied as an alternative to the straightforward averaging measurement describe above. The signal amplitude for each index in the arrays created by the sweeps are sorted and a result array based middle values, i.e. median algorithm, are used for detecting the peaks. To further improve the measurement a delay may be applied between the sweeps to allow the object of interest change or move slightly, eg. water surface.

THRESHOLD

To be able to determine if any objects are present, the measurement needs to be compared to a threshold. Here, three different thresholds can be employed, each suitable for different use-cases.

Fixed threshold

The simple approach to setting the threshold is choosing a fixed threshold over the full range. This approach requires that no background objects are present that can trigger detection.

CFAR (Constant False Alarm Rate) threshold

A final method to construct a threshold for a certain distance is to use the envelope signal from neighboring distances *from the same sweep*. This requires that the object gives rise to a single strong peak, such as a water surface and not, for example, the level in a large waste container. The main advantage is that memory consumption is minimal and that no noise normalization is required.

When using CFAR threshold, no detections will be made outside of range $[\text{range_start} + (\text{guard} / 2) + \text{window}, \text{range_end} - (\text{guard} / 2) - \text{window}]$.

For example, if the range is set to 0,20m / 4,8m and the guard = 0,2 and window = 0,09 the practical range will be:

$$\text{range} = 0,2 + (0,2 / 2) + 0,09, 4,8 + 0,2 - (0,2 / 2) - 0,09] = 0,39, 4,81$$

PEAK SORTING

Depending on the case, one is often the most important. Therefore, several different peak sorting methods are available.

For example, if the threshold is low (high sensitivity), the noise can give false alarms and the strongest peak is probably of interest. With a high threshold, on the other hand, all detected peaks are likely real objects, and the closest peak is probably of highest interest.

Closest

This method simply sorts the peaks by distance, with the closest first.

Most distant

As for the closest peak the most distant peak may be of interest, eg. in a well with obstacles that may give strong reflections in a closer distance than the water surface below.

Strongest

Here, the peaks are sorted after their envelope amplitude, with the strongest first.

Strongest reflector

This method will compensate for that the same object at a larger distance from the radar will give a weaker signal.

Strongest flat reflector

For large flat reflectors, such as fluid surfaces, the radar equation from the previous section is slightly modified.

ADAPTIVE RANGE

Only for test purpose.

PARAMETERS

System and Method parameters

Method	Command	Parameter name	Type	Default	Max	Min	Common settings	Warning value	Warning text	Help text
System sys:										
		Selected Method	integer	0	6	0	Yes			The current selected method
		Advertisement Interval (ms)	integer	250			No			System parameters - do not change
		Advertisement timeout (s)	integer	4			No			System parameters - do not change
		2.4 GHz radio protocol mode	integer	0	2	0	Yes		Setting = 2 (Long range only) is not supported by mobile phones and should normally not be selected!	0 = Normal range, 1 = Alternating normal range / long range, 2 = Long range only
		Tx power	integer	8			No			System parameters - do not change
		Radar on	boolean	0	1	0	Yes			Turn radar off=0 / on=1
		Network configuration	integer	1	3	1	No	2	If 2 is selected, wake up the 2.4 GHz RF with an NFC wake up (position an NFC enabled mobile phone in close proximity above Puck Radar until the phone vibrates)	1= 2.4 GHz RF, 2= LoRaWAN, 3= 2.4 GHz & LoRaWAN.
		Send on Change	boolean	0			no	---	---	- Not implemented -
		Periodic advertisement of 2.4 GHz RF signal (s)	Integer	0			Yes			Time between periodic advertisements in addition to those that occur during measurement. If this is greater than zero and less than the interval for the current method, advertising is started with this periodicity. Default value is zero.
		Timeout of the 2.4 GHz RF signal periodic advertisement (s)	integer	10						Specifies how long the advertisement should be active in the case of periodic advertisement. The periodic advertisement will always be done using the normal 2.4 GHz range. This also applies to the advertising that starts on cold start.
		Timeout of the 2.4 GHz RF signal advertisement after a detected NFC signal (s)	integer	20			No			Specifies how long, in seconds, it is announced after an NFC signal is detected.
		Secure Mode for LoRa interface	boolean	0			No			Specifies how long, in seconds, to wait after cold start before communicating with the LoRaWAN module.

		Distance in mm for Lora	boolean	0			No			- Not implemented -
Distance	1:									
		Measurement cycle (s)	integer	60	10		Yes			The time between each radar measurement
		HW acceleration average samples	integer	30	1	63	No			Number of radar measurements in a single radar scan. Increased value will reduce noise. This may improve the radar precision but will decrease battery length.
		Start of range (m)	float	0.200			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Length of range (m)	float	4.800			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Average factor	float	1.00	1	100	No			Number of radar scans in a single measurement cycle. Should normally be 1 but can be increased to handle rain/snow or a moving water surface to establish a more stable measurement. NOTE: The average factor will decrease the battery life with the same factor. Battery life is ¼ if the average factor is changed to 4.
		Peak sorting	integer	2	0	4				0 = closest, 1 = strongest, 2 = strongest reflector, 3 = strongest flat reflector, 4 = most distant, in case 'reflector' is mentioned, the decrease in amplitude over distance is accounted for
		Threshold type	integer	2	0	2				0 = fixed threshold; the parameter with 'fixed...' apply, 2 = cfar; the parameters below with 'cfar...' apply"
		Fixed threshold	integer	200			No			High threshold, require higher amplitude on echo.
		cfar sensitivity level	float	0.650			Yes			Increase the sensitivity level if Puck Radar often fails to detect an object within the defined range (reporting distance 0). Decrease the sensitivity level if Puck radar often reports echoes from incorrect radar paths (fig. 1)
		cfar threshold guard	float	0.200	0.2	0.01	No			- System parameter, do not change -
		cfar threshold window	float	0.090	0.2	0.01	No			Measurement point window in meter Explain better! Måts varje punkt +/- 9/4.5 cm? Måste man då ha max range = botten -10/5 cm?
		Offset	integer	0			No			- Not implemented -
		Adaptive Range	float	0			Yes			Only for test purpose.
		Median filter	boolean	1			No			Enable Median filter, 0 = function off, 1 = median function on" override CFAR measurement settings and Sensitivity level. Instead, the Median threshold is applied.
		Median threshold	integer	200			No			High threshold, require higher amplitude on echo.
		Median sweep delay	integer	1000			Yes			The value in ms is the delay between each measurment. 0 = no delay
		Profile	integer	2			Yes		High value consumes more energy	Specifies the profile, High value provides higher SNR and allows longer distances

		Debug	integer	0			No			- Not implemented -
Well	3:									
		Measurement cycle (s)	integer	60	10		Yes			The time between each radar measurement
		HW acceleration average samples	integer	30	1	63	No			Number of radar measurements in a single radar scan. Increased value will reduce noise. This may improve the radar precision but will decrease battery length.
		Start of range (m)	float	0.200			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Length of range (m)	float	4.800			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Average factor	float	1.00	1	100	No			Number of radar scans in a single measurement cycle. Should normally be 1 but can be increased to handle rain/snow or a moving water surface to establish a more stable measurement. NOTE: The average factor will decrease the battery life with the same factor. Battery life is ¼ if the average factor is changed to 4.
		Sensitivity level (unit?)	float	0.650			Yes			Increase the sensitivity level if Puck Radar often fails to detect an object within the defined range (reporting distance 0). Decrease the sensitivity level if Puck radar often reports echoes from incorrect radar paths (fig. 1)
		cfar threshold guard	float	0.200	0.2	0.01	No			- System parameter, do not change -
		cfar threshold window	float	0.090	0.2	0.01	No			Measurement point window in meter Explain better! Måts varje punkt +/- 9/4.5 cm? Måste man då ha max range = botten -10/5 cm?
		Offset	integer	0			No			- Not implemented -
		Adaptive Range	float	0			Yes			Only for test purpose.
		Median filter	boolean	1			No			Enable Median filter, 0 = function off, 1 = median function on" override CFAR measurement settings and Sensitivity level. Instead, the Median threshold is applied.
		Median threshold	integer	200			No			High threshold, require higher amplitude on echo.
		Median sweep delay	integer	1000			Yes			The value in ms is the delay between each measurment. 0 = no delay
		Profile	integer	2			Yes		High value consumes more energy	Specifies the profile, High value provides higher SNR and allows longer distances
		Debug	integer	0			No			Enable debug feature, 0: debug off, 1: debug on, current effect is that amplitude is reported regardless of the echo is above the threshold or not. In case it's below the distance will be zero.
Bin	4:									
		Measurement cycle (s)	integer	30	10		Yes			The time between each radar measurement

		HW acceleration average samples	integer	50	1	63	No			Number of radar measurements in a single radar scan. Increased value will reduce noise. This may improve the radar precision but will decrease battery length.
		Start of range (m)	float	0.150			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Length of range (m)	float	1.000			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Threshold level	integer	290			Yes			Threshold level. Decrease level to detect more. Increase level to get fewer detections. Adjust for different waste materials. Metal waste is very reflective, and the threshold can be increased. Paper is less reflective, and the threshold level may be reduced for a proper performance.
Parking 5:										
		Measurement cycle (s)	integer	15	10		Yes			The time between each radar measurement
		HW acceleration average samples	integer	10	1	63	No			Number of radar measurements in a single radar scan. Increased value will reduce noise. This may improve the radar precision but will decrease battery length.
		Start of range (m)	float	0.200			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Length of range (m)	float	1.500			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
Seating 6:										
		Measurement cycle (s)	integer	30	10		Yes			The time between each radar measurement
		HW acceleration average samples	integer	50	1	63	No			Number of radar measurements in a single radar scan. Increased value will reduce noise. This may improve the radar precision but will decrease battery length.
		Start of range (m)	float	0.150			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Length of range (m)	float	1.000			Yes			Start of range + Length of range = maximum 5 meter. The start and end values will be rounded to the closest measurement point available.
		Threshold level	integer	290	1	20000	Yes			Threshold level. Decrease level to detect more. Increase level to get fewer detections. Adjust for different environments and distance from the seating/object.
		Offset		0			no			- Not implemented -
		Required occupied detection	integer	3			yes			Number of consecutive 'occupied' detection needed to change to 'occupied'
		Required free detection	integer	3			yes			Number of consecutive 'free' detection needed to change to 'free'