77G millimeter-wave radar

R77ABH1

Breath & heartbeat radar

Data Book v1.0

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1. Product introduction

1.1 Product introduction

The breath & heartbeat radar works in the millimeter wave band of 77 GHz. It is a radar detection module that realizes real-time sensing and measurement of respiratory rate and cardiac rhythm of human bodies. Based on the FMCW radar system, this module detects the echoes reflected from the skin and calculates the variation of distance of target points and subtle motion on body surface to realize detection of ECG signals of human bodies.

Radar frequency band	77G millimeter-wave radar
Number of antennas	2T4R
Detection mechanism	FMCW
Active detection	Breath & heartbeat detection

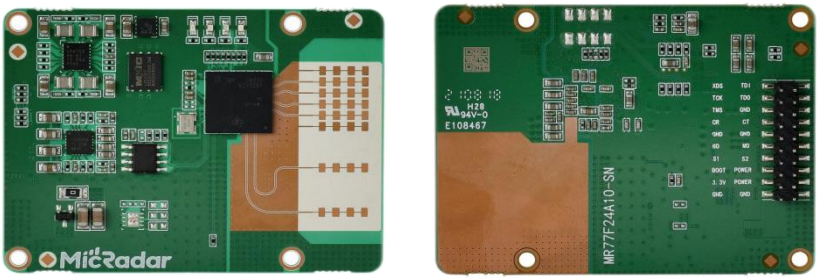

Fig. 1: Front and back sides of the radar

1.2 Theory of operation

The radar antenna transmits electromagnetic wave signals, and synchronically receives reflected echo signals. Then, the radar analyzes the phase difference and energy change between waveform parameters of the echo signals from varying antennas, and gives feedback on subtle motion power change, distance, orientation, speed, and other information of the target. This makes it possible to detect the motion state and chest expansion frequency / status of the target.

1.3 Product features

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- 77 GHz radar sensor;
- 2T4R MIMO antenna;
- Realizing radar detection through FWCW (frequency modulated continuous wave);
- Realizing synchronous sensing of respiratory rate and cardiac rhythm of human bodies;
- Observation distance of breath and heartbeat: 0.1 - 2 m
- Free from the influences of temperature, humidity, noise, air flow, dust, lighting, etc.

1.4 Applications

- Health monitoring;
- Health care monitoring;
- Infant monitoring
- Care for the aged;
- Sickbed monitoring;
- Physiological monitoring for important / high-risk persons

2. Product encapsulation diagram

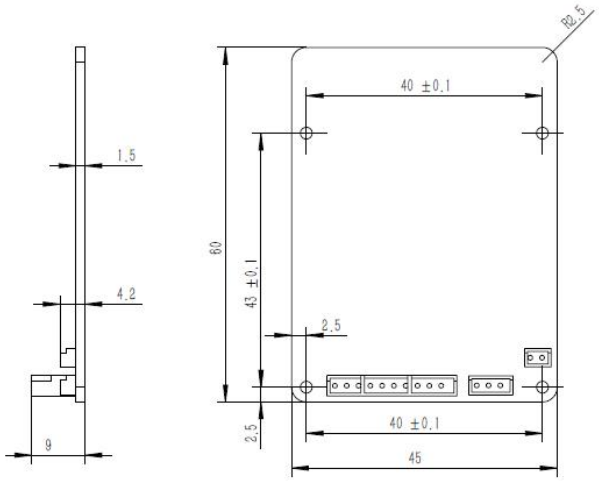

Fig. 2: Schematic diagram for radar module frame

- Volume: ≤ 60 mm * 45 mm * 5 mm
- Interface: UART / CAN

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3. Product features

This module features the following:

- This module is capable of observing the distance between a human body and the radar;
- This module is capable of real-time detection on respiratory rate (RESP) and pulse rate (PR) of human bodies;
- The module is of small output power and hence harmless to health;
- The module is immune to temperature, lighting, dust and other ambient factors while bearing high sensitivity.

4. Primary parameters

Parameter	Minimum	Typical value	Maximum	Unit
Performance				
Detection distance (chest)	0.1		2	m
Detection distance (back)	0.05		0.5	m
Measurement accuracy of breath		90		%
Measurement accuracy of heartbeat		90		%
Refresh time	1		60	S
Establishment time of observation		20		S
Working Parameters				
Working voltage (VCC)	4.6	5	6	V
Working current (I_{CC})		250	300	mA
Working temperature (T_{OP})	-20		60	℃
Storage temperature (T_{ST})	-40		80	℃
Transmission parameter				
Working frequency (f_{TX})		77	78	GHz
Transmission power (P_{out})	8	10	12	dBm

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Parameters of antenna				
Antenna gain (G_{ANT})		12		dBi
Horizontal beam (-3 dB)	-40		40	°
Vertical beam (-3 dB)	-20		20	°

5. Module dimensions and pin explanation

5.1. Module dimensions

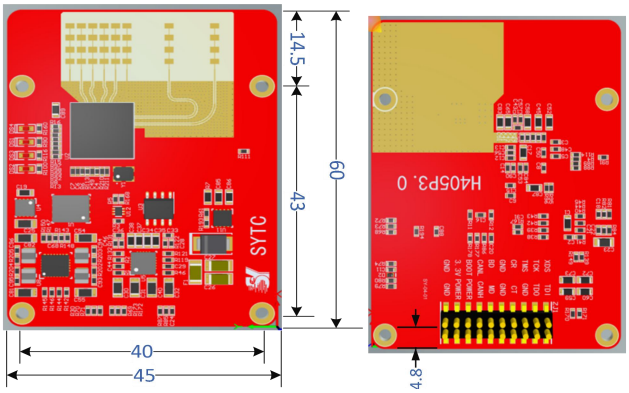
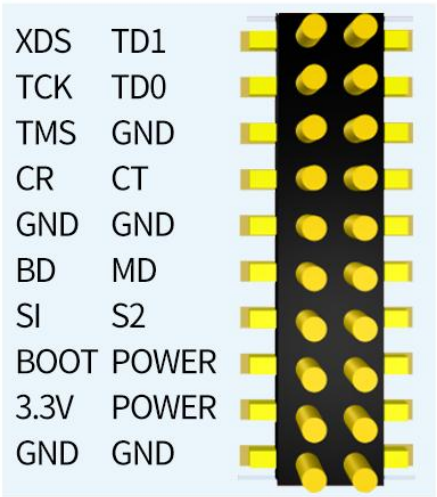


Fig. 3 Overall dimensions of 77 GHz breath & heartbeat radar

5.2 Description of interfaces

This radar module is provided with a 20-pin external interface with PH2.0 mm and 2*10 pins, as illustrated below. Some of the interfaces are for radar configuration or reserved for other products.



NRST	TDI
TCK	TDO
TMS	GND
CR	CT
GND	GND
BD	MD
S1	S2
BOOT	+5V
V33	+5V
GND	GND

Fig. 4 Pins of 77 GHz breath & heartbeat radar

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Interface definitions for products of this model are given in the table below.

	Pin	Notes	Remarks
1	CRX	Configuration send port	This is the port for radar control by the host. It doesn't have to be connected, in which case the radar will run with default parameters.
2	CTX	Configuration receive port	
3	MD	Data output port	The port for data output by the radar.
4	+5V	Input +5.0 power supply	The input end of radar power supply. Working current of radar ≥ 600 mA
5	V33	Output +3.3 V	External power supply port, current ≤ 150 mA

6.Working mode of module

6.1 Radar module coverage

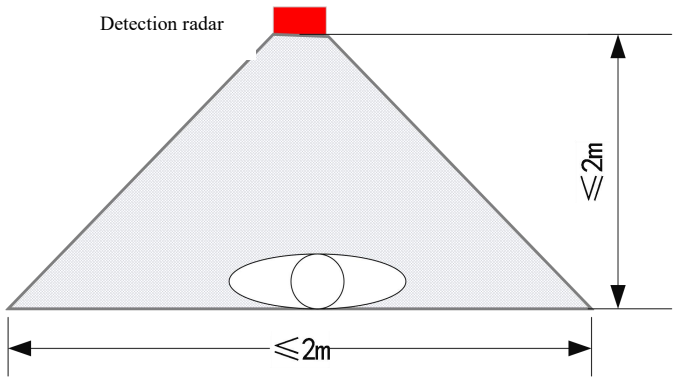

Fig. 5 Detection coverage of 77 GHz breath & heartbeat radar

When the radar is working, its working surface should be aligned right with the chest or back of the person under detection as far as possible. The body-radar distance should be ≤ 2 m.

6.2 Radar connection

The connection between the radar and the peripheral host is as illustrated in Fig. 6 below. There are 3 kinds of ports between the radar and peripherals, i.e. the data port, control port, and mode selection port.

Data port:

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- This is the output port for radar detection data. For details on parameters and models, see Section 5 Module interface protocol.
- This port is a must for radar connection.

Control port:

- Through this port, the host is able to further operate the radar, e.g. inquiring device IDs, controlling device status, altering working modes of the device, etc.
- Normally, this port is preferably not connected, and the radar runs directly with default parameters.
- For data protocol of this port, see product protocol specifications.

Mode selection port:

This port provides a more direct method for radar control, that is, in case of high level for CANL port, the radar runs properly; while in case of low level, the radar will be on standby.

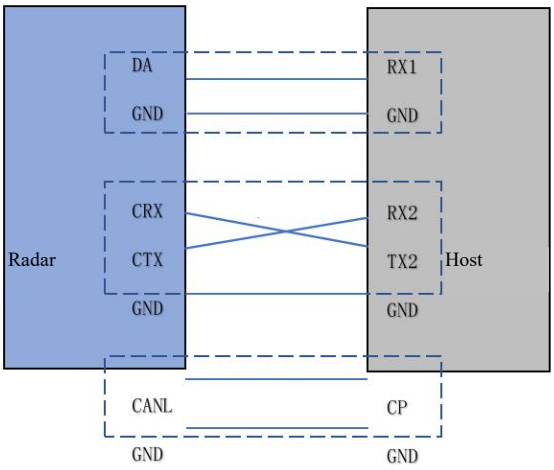

Fig. 6 Connection between the radar and the host

7. Installation method

The radar works mainly based on the rise and fall of skin surface arising from breath and heartbeat, which is more noticeable at the chest and the back. On this account, this radar should be installed facing right to the chest or back of the person under detection.

Considering the work principles, the following methods are suggested for radar mounting:

Top mounting:

To fulfill the needs of people lying in bed or sleeping, top mounting (as shown in Fig. 7) is employed so that the beam heads directly to the body and the center of the beam is aligned with the chest.

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In this mounting mode, the radar-body distance should be ≤ 2 m.

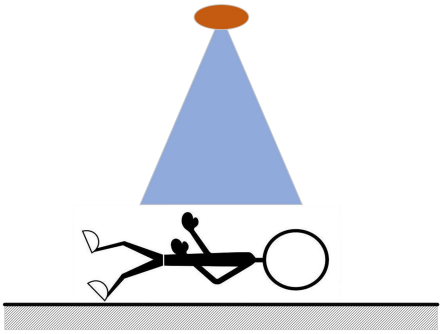

Fig. 7 Diagram of top mounting

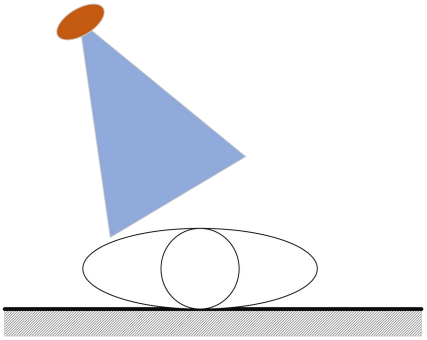

Fig. 8 Diagram of inclined mounting

Inclined installation:

In case of inclined mounting, the radar is fixed onto a wall or beside a bed, inclined (as shown in Fig. 8). The beam from the radar covers the body at an angle. The center of the beam is aligned with the chest.

In this mounting mode, the radar-body radial distance should be ≤ 2 m.

Horizontal mounting:

The radar is laid horizontal (as shown in Fig. 9), and fixed onto a wall or on a desk. The beam from the radar covers the body perpendicularly. The center of the beam is aligned with the chest.

In this mounting mode, the radar-body distance should be ≤ 2 m.

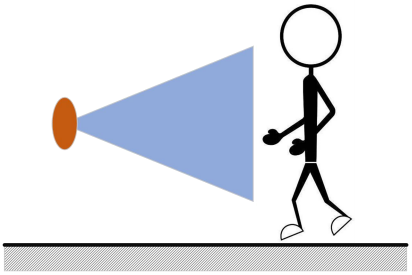

Fig. 9 Horizontal mounting diagram

Fig. 10 Back mounting

Back mounting:

The radar is installed at the corresponding point of a chair or a bed cushion, spaced from the body by non-metallic media (as shown in Fig. 10).

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In this mounting mode, the radar realizes breath and cardiac rhythm measurement mainly by detecting the motion of body surface on the back.

In this mode, the effective measurement distance between the radar and the body is 5 cm - 50 cm..

8. Module interface protocol

8.1 Introduction of interfaces

The radar module communicates with the host through a serial port, definition of which is described below:

- Interface level: CMOS
- Baud rate: 115200bps
- Stop bit: 1
- Data bit: 8

Data is output in little-endian mode.

8.2 Definitions of output data frames

A data frame is the frame of data transmitted from the radar to the client. Its structure is shown in Fig. 11.

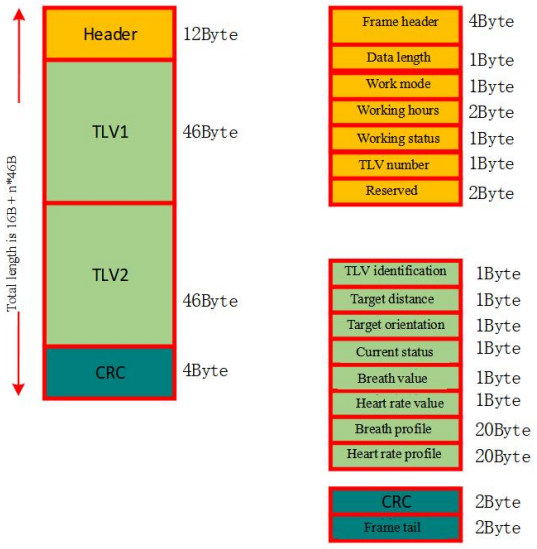

Fig. 11 Data structure of uplink frames

An uplink frame comprises 3 parts, i.e. frame header, parameter field, and verification field.

Below are the definitions for the three kinds of frame data:

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A.Header Total length: 12 Byte

	Symbol	Definition	Length (B)	Notes	Remarks
1	SYNC	Leading character	4	Fixed as “0x53 0x59 0x54 0x43”	Set as SYTC
2	Length	Data length	1	Indication of length for the entire data frame;	Counted as bytes
3	Mode	Work mode	1	0x00 - Standby mode; 0x01 - Forward wide detection mode; 0x02 - Back detection mode; 0x03 - Forward narrow mode; 0x04 - Forward tracking mode; 0x06 - Dual-person monitoring mode;	
4	Time	Working hours	2	Time for radar to work upon booting, “min.”	
5	NumTLV	TLV number	1	Number of persons whose breath & heart rate are detected	
6	WorkCon	Working status	1	Current working status of the radar 1-Working properly 2-Standby 3-Exception	
7	Reserve	Reserved	2	Reserved field	

B.Parameter fields Length: 46 Byte

	Symbol	Definition	Length (B)	Notes
1		TLV identification	1	TLV sub-frame identification: “0x01” and ”0x02” represents the first and the second positions respectively

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2		Target distance	1	Int, 0.1 m in precision, 0 - 25.6 m
3		Target orientation	1	Int, 1° in precision, -127° - 128°
4		Current status	1	0x01 - Normal state; 0x02 - Exception state;
5		Breath value	1	Int
6		Heart rate value	1	Int
7		Breath profile	20	8 bits int
8		Heart rate profile	20	8 bits int

Notes: When there is more than one target, target parameters are sorted by distance.

C.Verification field

	Symbol	Definition	Length	Notes
1	CRC	CRC	2B	CRC16
2	ZW	Frame tail identification	2B	“0xEE 0xEE”

9. Notes

9.1 Start-up time

The module needs to fully reset its internal circuits and performs a full assessment on ambient noise when it is powered on and starts to work, so as to ensure the module can work properly. As a result, the module requires a stabling time ≥ 30 s upon powering on to ensure the effectiveness of parameters output subsequently.

9.2 Limits of heartbeat measurement

Given the nature of this module - a breath & heartbeat detection radar - keeping a short distance of detection is recommended. The appropriate distance ranges from 0.1 m - 2 m.

If an object with higher reflectivity exists in vicinity of the measurement target, the radar might track the object instead, causing a parameter exception for radar detection, in case of which the radar should be relocated.

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Please note that for now, measurement of this radar module is limited to a single target only. Therefore, if more than one person is in the detection area, the parameters will be subject to disorder.

9.3 Bio-detection performance of radar

The distance of detection of the radar module depends mainly on target RCS and environmental factors, and might vary with the environment and the target. This module is not provided with distance measurement feature for now, and hence it's normal for the effective distance of detection to fluctuate in a certain range.

9.4 Power source

The radar module has requirements higher than regular low-frequency circuits on power source quality. When supplying power to the module, the power source is required to be free from any threshold glitches or ripples, and can effectively shield power supply noise from accessories.

The radar module requires proper grounding. Ground noise from other circuits might compromise the performance or even cause an anomaly in the module. A reduced distance of detection or increased false alarm rate is one of the commonest.

To ensure the VCO circuit inside the module works properly, power supply to this module should be +5V - +6V, with ripple voltage ≤ 100 mV.

External power supply must be able to provide sufficient current output and transient response capacity.

10. Disclaimer

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13. Description of versions

Revision	Release Data	Summary	Author
V0.4		First draft	Mark
V0.5		Modified model display(R77BHM1) -> (R77ABH1)	Mark
V1.0 03-15	3/15/2023	Adjusted the composition of the front portion of the document	Annie