433 modem test firmware specifications

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Introduction

This document lists the firmware specifications of the 433 modem. This firmware can be used to test the device's functionality and working condition. Software interface to control the modem is specified in `433 modem control protocol specifications`. Modem hardware specifications are listed in `433 modem hardware specifications`.

Target audience: firmware developers and testers.

General

Licensing

This firmware is licensed under `GNU LESSER GENERAL PUBLIC LICENSE Version 2`.

Vocabulary

Term	Definition
ACM	Abstract Control Model
ASCII	American Standard Code for Information Interchange
CDC	Communications Device Class
GPIO	General Purpose Input/Output
LED	Light-emitting diode
OOK	On-Off Keying
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
Rx	Receive
Tx	Transmit

Firmware description

The complete code that is deployed to the device consists of two parts:

- bootloader, and
- user code.

Bootloader

This is a customised CC-Bootloader.

The relevant bootloader can be downloaded from Vecly public download site.

User code

User code implements the functionality described below. Functionality is controlled via control protocol. After a particular command is used, the device's USB connection to the host PC can be disconnected. Modem will, however, still need to be connected to a power supply. This allows the user to operate the modem in interference free environments, for example to test RF parameters. User code has to be compiled in compliance with C1111F32 unified memory space addresses. See firmware project `Makefile` for used addresses.

Firmware functionality

The following functionality is implemented.

- Continuous unmodulated carrier transmission on a selected channel with selected Tx Power.
- Continuous carrier reception and RSSI indication.
- Periodic static text transmission via FSK waveform.
- Periodic static text transmission via GFSK waveform.
- Periodic test reception via GFSK waveform.
- Bootloader launch without power cycle.
- Firmware name and version reporting.
- LEDs test (GPIOs in CC-Debugger interface or LED in Texas Instruments' USB evaluation board) by switching all the LEDs on and off.
- Safety timer test, which is triggered after a predetermined period of time.

The transceiver implements the following radio state machine patterns:

- Transmit > Idle
- Receive > Idle

All transmission and reception modes employ safety timer: transceiver is switched to idle and operating mode is "cleared" after a predetermined period of time.

Aforementioned functionalities meet the requirements of the tests that have been listed in `ETSI EN 300 220-1 V2.4.1 - Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Technical characteristics and test methods`.

In addition, LEDs indication via `CC debugger interface` can be used, if run with appropriate hardware definition and connected to a LED board (active by default) as described below.

Timer periods

Timer	Period in seconds
Tx/Rx safety timer	600
Safety test timer	10
LED test timer	30
Periodic Tx delay	3
Bootloader start delay	2

Control protocol commands reference

Following table lists the commands implemented in this firmware.

From host PC to modem

Command	Description
0x02	Launch bootloader to allow modem firmware (user code) update
0x03	Request modem firmware name
0x04	Request modem firmware version
0x06	Set TX power
0x07	Set RF channel
0x08	Activate transceiver idle mode
0x0a	Set RSSI reporting
0x10	Transmit unmodulated carrier
0x11	Report received carrier RSSI
0x12	Static text periodic transmission in ASK
0x13	Static text periodic transmission in GFSK
0x14	Reception in GFSK
0x15	Test LEDs
0x16	Test safety timer

Responses and reports from modem to host

Command	Arguments	Description
0x03	NAME	Modem firmware name
0x04	VER	Modem firmware version
0x0a	RSSI	Report of RSSI of last RX. Byte RSSI contains RSSI value `0..100`
0xFF		Modem status messages
	0x01	Command not implemented
	0x02	Safety timer was triggered

Host interface and drivers

Test firmware can be run from host via USB CDC-ACM driver. The modem is exposed to the host as a serial device, for example as `/dev/ttyACMx`.

Linux driver is included in newer distributions, Windows users have to download publicly available third party drivers. These can be downloaded from Vecly public download site.

Common Air interface

Common RF parameters

Parameter	Value
Channel spacing	100 kHz
Data rate	38,8 kBaud
Sync word	0xD3 0x91
Modulations	OOK/2-FSK/GFSK
Deviation for FSK	16 kHz
Deviation for GFSK	20 kHz
Manchester	IEEE 802.3
Sync word detection	30/32 bits
Preamble	8 bytes
Rx filter bandwidth	100 kHz

Frequencies and channels

Following table lists frequencies which can be set as channels via control protocol.

Channel	Frequency
1	433,8 MHz
2	433,9 MHz
3	434,0 MHz
4	434,1 MHz
5	434,2 MHz
6	433,6 MHz
7	433,5 MHz

`7` is default channel.

Tx power

Following table lists power levels which can be set via control protocol.

Level	Tx power
7	10 dBm
6	7 dBm
5	5 dBm
4	0 dBm
3	-5 dBm
2	-10 dBm
1	-15 dBm
0	-20 dBm

`10 dBm` is default Tx power.

Continuous unmodulated carrier transmission

In this mode, the modem transmits random data in OOK mode. Unmodulated carrier Tx is achieved by setting equal Tx power for both logic 0 and logic 1.

Red LED lights up while the modem is in Tx.

When it is activated, the transceiver is switched to Tx and kept in Tx until another command is sent to the modem or until the safety timeout occurs.

Continuous carrier reception and RSSI indication

Continuous RSSI indication is achieved by using the OOK mode and configuring the modem to receive all data without sync word detection.

The modem continuously reports the last received RSSI value, until the mode is changed.

Reported RSSI is recalculated to real RSSI values by using the formula below.

```
If RSSI_dec ≥ 128 then RSSI_dBm = (RSSI_dec – 256)/2 – RSSI_offset
Else if RSSI_dec < 128 then RSSI_dBm = (RSSI_dec)/2 – RSSI_offset
```

RSSI_offset should be `74`.

Red LED lights up while in Rx.

The strength of the signal received is indicated with the LEDs as listed in following table.

RSSI	Blue LED	White LED	Green LED
< - 70 dBm	-	-	-
> - 60 dBm	+	-	-
> - 50 dBm	+	+	-
> - 40 dBm	+	+	+

NB! Please keep in mind that the 433 modem is not a measurement equipment and the indicated RSSI is not precise.

In this mode, the modem is switched to Rx and kept in Rx until another command is sent to the modem or until the safety timeout occurs.

Periodic static text transmission via FSK or GFSK waveforms

In this mode, modem transmits static ASCII text `Hello World from 433 modem`. Text payload is preceded with text length byte to enable reception with Texas Instruments SmartRF Studio.

Modulation and deviation are different for FSK and GFSK.

Transmission is repeated periodically, as per a predetermined time period, until another command is sent to the modem or until the safety timeout occurs.

Red LED lights up while in Tx.

Periodic test reception via GFSK waveform

In this mode, the modem continuously tries to detect sync word and receive data after the sync word is detected. First byte is the payload length. After reading length byte, the modem stays in Rx until complete payload is received or the safety timeout occurs (this enables to send data with Texas Instruments SmartRF Studio). After the complete payload is received, it is sent to the host PC. When RSSI reporting is set to continuous report, the payload is preceded with RSSI indication message.

Red LED lights up while the modem is in Rx. When RSSI reporting is set to continuous report, LEDs indicate the RSSI the same way as in unmodulated Rx.

In this mode, the modem is switched to Rx and kept in Rx until another command is sent to the modem or until safety timeout occurs.

Modem local operations not receiving or transmitting

Bootloader launch without power cycle

In order to speed up firmware updates and avoid unnecessary power cycles, the bootloader can be launched from user code. This enables user code update via `bootload.py` that has been included in the CC-Bootloader package.

NB! Please keep in mind that BMS switch on the modem has to be in position 1. Otherwise the bootloader executes user code immediately after "reboot" and the user code can not be updated.

Firmware name and version reporting

The modem reports deployed firmware name or version as ASCII text after the relevant command is sent to the modem.

LEDs test

This command switches all LEDs on or off. When LEDs are switched on, they stay on until the timeout mentioned above occurs.

Safety timer test

This command sets the safety timer to period mentioned above. When timer event occurs, the modem sends an indication via command protocol.