APPLICATION NOTE

Atmel AT03911: REB233CBB Module – User Manual

Atmel MCU Wireless

Features

- REB233CBB Module targeted for IEEE 802.15.4®, ZigBee®, ZigBee RF4CE, 6LoWPAN and ISM applications
  - Industry leading 101dB link budget
  - Ulta-low current consumption
  - Ultra-low supply voltage (1.8V to 3.6V)
- Hardware supported antenna diversity
- Board information EEPROM
  - MAC address
  - Board identification, features, and serial number
- Powered by two AAA batteries for stand-alone operation

Introduction

This manual introduces the Atmel® REB233CBB Module, a module consisting of an Atmel AT86RF233 radio transceiver and Atmel ATxmega256A3 microcontroller forming a fully functional wireless node. Detailed information is given in the individual sections about the REB233CBB Module assembly, functionality, interfaces, and usage.

Figure 1-1. REB233CBB Module.

Table of Contents

2. Disclaimer

Typical values contained in this application note are based on simulations and testing of individual examples.

Any information about third-party materials or parts was included in this document for convenience. The vendor may have changed the information that has been published. Check the individual vendor information for the latest changes.

3. Overview

The REB233CBB Module is a compact solution providing wireless connectivity between IEEE 802.15.4/ZigBee compliant devices. The module is compliant to EU and US regulatory requirements.

The REB233CBB Module is an ideal platform to:

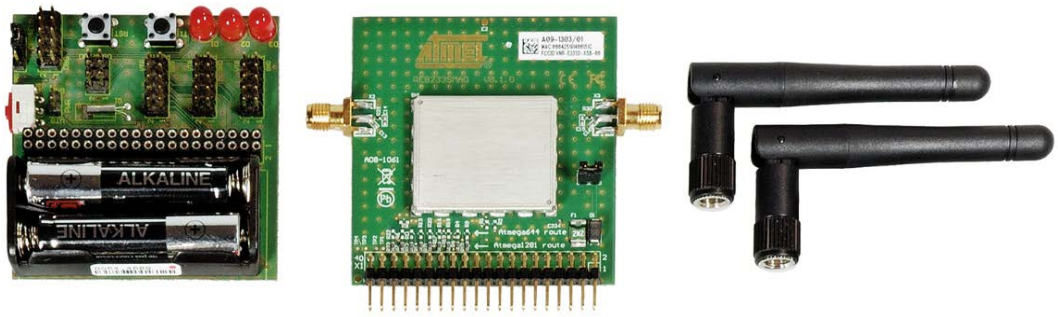
- Become familiar with a ready-to-use radio product by Atmel
  - No configuration required for out-of-box experience
- Evaluate the outstanding REB233CBB Module performance, such as
  - Excellent receiver sensitivity achieved at ultra-low current consumption
  - Performance improvements and robustness by operating antenna diversity
- Test the REB233CBB Module hardware support of the IEEE 802.15.4 standard [1]

4. Assembly instructions

4.1 Delivery state

The REB233CBB Module is delivered in dismounted state. Figure 4-1 shows the Microcontroller PCB with batteries inserted, the Radio PCB and two swivel antennas.

Figure 4-1. REB233CBB Module delivery state



4.2 Preparing the REB233CBB Module

Follow these steps to setup the REB233CBB Module for correct operation:

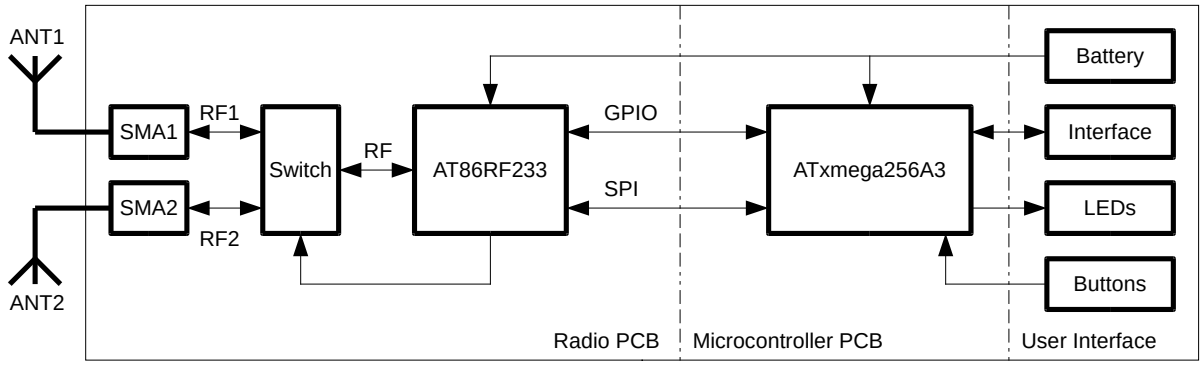
1. Check or set the power switch off at the Microcontroller PCB.
2. Insert the two delivered batteries and check for correct polarization.
3. The RF-Shielding of the Radio PCB must be faced to the battery holder of the Microcontroller PCB. Plug in the Radio PCB header '*X1*' into the Microcontroller PCB socket '*Expand 1*'.
4. The swivel antennas provided with the REB233CBB Module are tested and approved (see A.3). One antenna must be mounted on each SMA coaxial connector '*X2*' and '*X3*' port of the Radio PCB.

Note, to ensure compliance, the use of any other antenna type is not permitted, see A.3.

5. Functional description

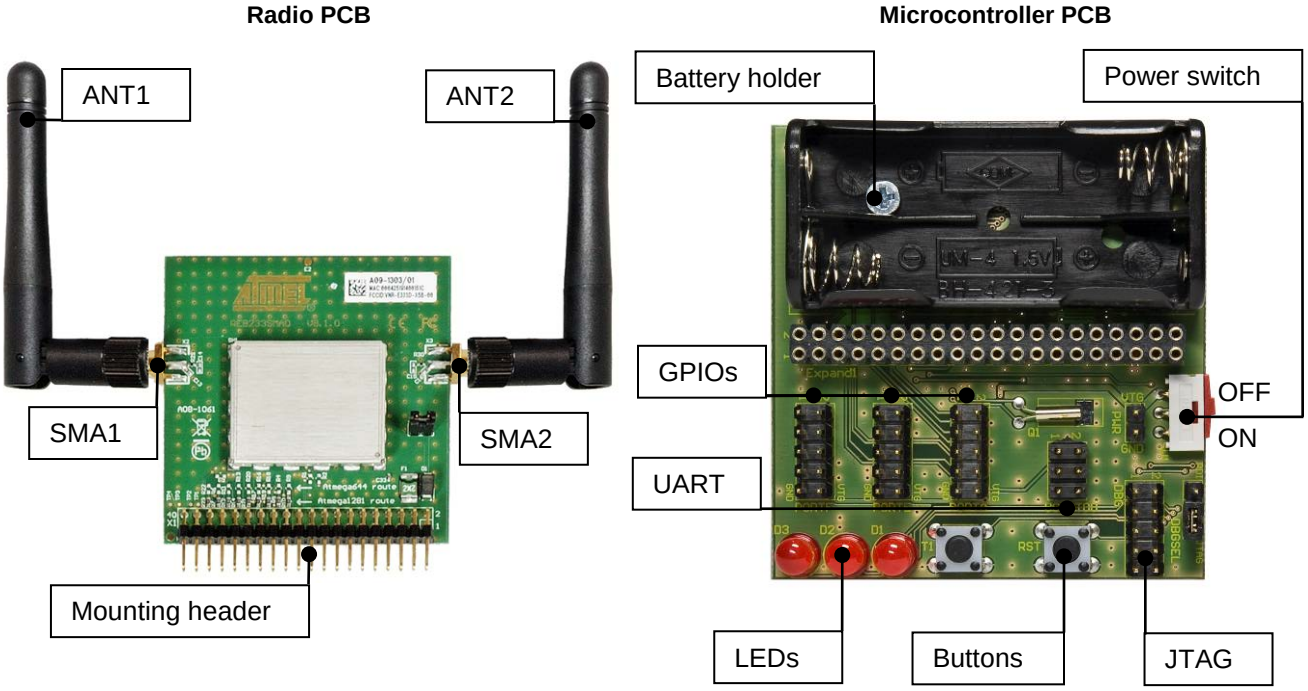
The block diagram of the REB233CBB Module is shown in Figure 5-1. The Radio PCB and Microcontroller PCB are connected via a mounting header. The Radio PCB is not functional without connecting it correctly to the Microcontroller PCB. The Radio PCB is equipped with two approved antennas; see A.3 and [2], to enable antenna diversity (AD) operation.The Microcontroller PCB controls the Radio PCB, provides the power supply as well as the user interface. The user interface consists of three LEDs and two pushbuttons for manual user control of the module. Additional microcontroller (MCU) GPIOs, like USART, UART and JTAG, are available to control the module with a host-PC.

Figure 5-1. REB233CBB Module block diagram



The two REB233CBB Module components, the Radio PCB, equipped with two swivel antennas, and Microcontroller PCB, are shown in detail in Figure 5-2. Here, the REB233CBB Module is dismounted for better explanation of all important hardware features.

Figure 5-2. REB233 Module features (dismounted view for better description)



5.2 Radio PCB

The Radio PCB carries the radio transceiver AT86RF233 [3]. The radio transceiver is a high performance RF-CMOS 2.4GHz radio transceiver targeted for IEEE802.15.4, ZigBee, RF4CE, 6LoWPAN, and ISM applications. The identification EEPROM carries Radio PCB information used by the Microcontroller PCB.

5.3 Antennas

The antennas intended for the REB233CBB Module, see A.3 and [2], are to be connected to the SMA connectors on the Radio PCB. A proper antenna orientation can enhance the radio link budget. Especially an orthogonal orientation between the two antennas, see Figure 6-1, decreases the probability of RF signal extinction.

5.4 Microcontroller PCB

The Microcontroller PCB carries the ATxmega256A3 MCU [4]. The MCU is a high-performance, low-power 8/16-bit Atmel AVR® XMEGA® MCU with 256KB in-system, self-programmable flash, 8KB boot code section with independent lock bits, 16KB internal SRAM and 4KB EEPROM.

5.5 Power Supply

The REB233CBB Module is powered by two AAA batteries. The power switch disconnects batteries from the entire board. External power is not routed through the power switch.

Note: There is no protection against over-voltage.

5.6 LEDs and buttons

For simple applications, and to provide status information, a user interface is provided on-board, consisting of three LEDs and two pushbuttons

The LEDs (D1…D3) are connected to PB0..2 for active-high operation, whereas the pushbutton (T1) pulls PB3 to GND. The second pushbutton (RESET) is connected to the MCUs reset pin.

Table 5-1. LED/Button connection

ATxmega256A3	I/O	ATxmega256A3	I/O
PB0 (6)	D1	PB3 (9)	T1
PB1 (7)	D2	RESET	T2
PB2 (8)	D3		

5.7 UART/USART

The signal lines for asynchronous serial operation of the Atmel ATxmega256A3 (USARTD0) are connected to header USARTD0. In addition, the MCU reset line is connected to pin 5 of this header. This can be used to work with a serial boot loader. No level conversion is done; therefore, an external RS232/TTL conversion circuit is required.

The header pin-out mates with the available RS232/TTL converter in Figure 5-3.

Table 5-2. Connection of USARTD0

ATxmega256A3	Header USARTD0	Description
PD2 (28)	RxD (4)	Asynchronous serial in
PD3 (29)	TxD (1)	Asynchronous serial out

ATxmega256A3	Header USARTD0	Description
RESET (57)	RESET (5)	MCU reset
	VTG (2)	Operating voltage
	GND (6)	Ground

Synchronous operation is not supported.

PC connectivity can be easily achieved by using a serial to USB level shifter stick [8] as shown in Figure 5-3.

Figure 5-3. USB level shifter stick.

5.8 ID EEPROM

The REB233CBB Module identifies the Radio PCB by checking the correct content of the Radio PCB identification (ID) EEPROM, which handles information about the Radio PCB, the node MAC address and production calibration values. This ensures no other Radio PCB type can be used in conjunction with the delivered Microcontroller PCB and firmware.

The firmware running on the Microcontroller PCB checks the correct content of the Radio PCB ID-EEPROM before continuing with any radio operation. In case of wrong or unexpected content of the Radio PCB ID-EEPROM the operation is stopped which is indicated by LEDs D1…D2 blinking.

Table 5-3 shows a detailed description of the Radio PCB ID-EEPROM data structure.

Table 5-3. ID EEPROM mapping.

Address	Name	Type	Description
0x00	MAC address	uint64	MAC address for the 802.15.4 node, little endian byte order
0x08	Serial number	uint64	Board serial number, little endian byte order
0x10	Board family	uint8	Internal board family identifier
0x11	Revision	uint8[3]	Board revision number ##.##.##
0x14	Feature	uint8	Board features, coded into seven bits 7 Reserved 6 Reserved 5 External LNA 4 External PA 3 Reserved 2 Diversity 1 Antenna 0 SMA connector
0x15	Cal OSC 16MHz	uint8	RF233 XTAL calibration value, register XTAL_TRIM
0x16	Cal RC 3.6V	uint8	Atmel ATxmega256A3 internal RC oscillator calibration value @ 3.6V
0x17	Cal RC 2.0V	uInt8	Atmel ATxmega256A3 internal RC oscillator calibration value @ 2.0V

Address	Name	Type	Description
0x18	Antenna gain	Int8	Antenna gain [resolution 1/10dBi]. For example, 15 will indicate a gain of 1.5dBi. The values 00h and FFh are per definition invalid. Zero or -0.1dBi has to be indicated as 01h or FEh
0x20	Board name	Char[30]	Textual board description
0x3E	CRC	Uint16	16-bit CRC checksum, standard ITU-T generator polynomial G16(x) = $x^{16} + x^{12} + x^5 + 1$

Note: MAC addresses used for this product are Atmel property. The use of these MAC addresses for development purposes is permitted.

6. Mechanical description

The mechanical dimensions of the REB233CBB Module are decribed in Figure 6-1 and Table 6-1.

Figure 6-1. REB233CBB Module with vertical (1) and horizontal (2) antenna position

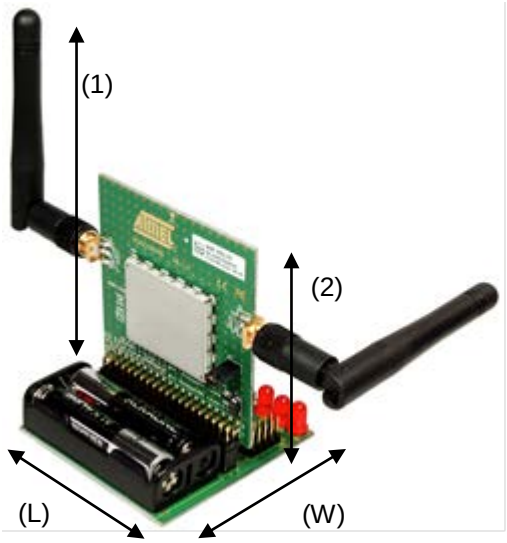


Table 6-1. REB233CBB Module mechanical dimensions

Dimension	Value
Length (L)	57mm
Width (W)	60mm
Height with vertical antenna position (1)	110mm
Height with horizontal antenna position (2)	70mm

7. Firmware description

7.1 Range measurement

The REB233CBB Module is pre-flashed with the RF performance test suite featuring a range measurement application. Each module operates in a standalone manner, and is able to transmit or receive data frames. A successful transmit or receive operation is indicated by a blinking LED.

7.1.1 Power up the modules

Apply power to both modules by switching on the power switch. In consequence of, a module runs a power-on check and indicates the successful completion by switching on the second of the three LEDs.

7.1.2 Run range measurement application

Select one of the REB233CBB Module and press pushbutton T1 to start the range measurement application.

First, the module initiates a connection and configuration procedure by sending broadcast frames and waiting for a response from the second module. After successful configuration, the module turns on LED-D1 indicating this status. The initiator starts transmitting data frames. Each data frame transmission is indicated by blinking the TX status LED-D2. A successful data frame reception on the second node is indicated by blinking the RX status LED-D3. The frame transmit repetition rate is fixed to ensure FCC compliance; the repetition rate cannot be changed.

The RX status LED stops blinking if no data frames are received, such as when, for example, the node has left the communication range. Data frame transmission can be stopped by pressing T1 once more on the node transmitting frames.

The REB233CBB Modules are able to transmit and receive simultaneously. Pressing pushbutton T1 on both nodes initiates each node to transmit frames. Operating modes are indicated as: LED-D1 a successful start-up, LED-D2 in transmit and LED-D3 in receive mode.

Note: The node configuration gets lost when resetting or switching off the radio modules power supply; to restart, a reset or power cycle is required for both REB233CBB Modules before pressing T1 on one (or both) REB233CBB Module(s).

7.2 Packet error rate measurement

The RF performance test suite features a packet error rate measurement (as defined by IEEE802.15.4), and allows to explore various radio transceiver features, radio transceiver registers, and performance by tuning with customized configurations. For this application, at least one REB233CBB Module needs to be connected to a PC.

7.2.1 Module preparation

1. Prepare REB233CBB Modules as described in Chapter 4.2.
2. Make sure that the power switch on both modules is in the off position.
3. Plug an USB level-shifter into a free USB port on your host-PC. Interconnect this adapter and one of the REB233CBB Modules via the 6-pin ribbon cable so that it fits the notch on the adapter and the colored stripe of the ribbon cable connects to pin 1 of the header *USARTD0*.

7.2.2 Driver installation

Download the USB adapter drivers from http://www.dresden-elektronik.de/shop/prod152.html?language=en, 'Downloads' tab and extract the archive to a folder of your selection. If the 'New Hardware Found' wizard prompts for drivers ignore Windows® update search ('No, not this time'). In the next dialog, select 'Install from a list or a specific location' and point at the extraction directory. Confirm installation, ignore warnings that the driver is not digitally signed or did not pass the Windows driver certification.

If no wizard pops up, install drivers manually via the device manager.

Note: The driver installation needs to be performed twice.

7.2.3 Set up the terminal program on the host-PC

A terminal program running on the host-PC is used to control the application running on the REB233CBB Modules.

Set up the terminal program as follows:

COM PORT:	Select COM port assigned during USB adapter driver installation
BAUD RATE:	9600
PARITY:	None
DATA BITS:	8
STOP BITS:	1
FLOW CONTROL:	Off

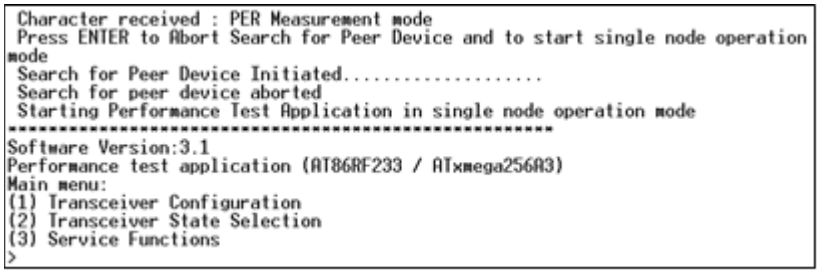
7.2.4 Power up REB233CBB Modules

Apply power to both (optional one) modules by switching on the power switch. The modules run a power-on check, and indicate the successful completion by switching on LED-D2.

7.2.5 Run the packet error rate measurement

Type any character in the terminal window (Figure 7-1) to initiate the configuration procedure for a REB233CBB Module. Optionally, if no peer node is active, the search for a peer device can be aborted by pressing ENTER to configure the module stand-alone operation. The packet error rate measurement can be operated through the menu options displayed on the UART terminal program.

Figure 7-1. Terminal window



8. Electrical characteristics

8.1 Absolute maximum ratings

Stresses beyond the values listed in Table 8-1 may cause permanent damage to the board. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this manual are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. For more details about these parameters, refer to individual datasheets of the components used.

Table 8-1. Absolute maximum ratings.

No.	Parameter	Condition	Minimum	Typical	Maximum	Unit
7.1.1	Storage temperature range		-40		+85	°C
7.1.2	Humidity	Non-condensing			90	% r.H.
7.1.3	Supply voltage		-0.3		+3.6	V
7.1.4	EXT I/O pin voltage		-0.3		V_{CC} + 0.3	V
7.1.5	Supply current from batteries	Sum over all power pins			+70	A
7.1.6	Battery Charge current(1)				0	mA

Note: 1. Keep power switch off or remove battery from REB233CBB Module when external power is supplied.

8.2 Recommended operating range

Table 8-2. Recommended operating range.

No.	Parameter	Condition	Minimum	Typical	Maximum	Unit
7.2.1	Operating temperature range	Crystal within ±40ppm	-10		+60	°C
7.2.2	Supply voltage (V_{CC})	Default	1.8	3.0	3.6	V
7.2.2		Serial flashaccess in usage	2.3	3.0	3.6	V

8.3 Current consumption

Test conditions (unless otherwise stated):

V_{DD} = 3.0V, T_{OP} = 25°C

Table 8-3 lists current consumption values for typical scenarios of the REB233CBB Module.

Table 8-3. Current consumption of REB233CBB Module

No.	Parameter	Condition	Minimum	Typical	Maximum	Unit
7.3.1	Supply current(1)	MCU @ power down, transceiver in state SLEEP, serial flash in Deep-Sleep		17		µA
7.3.2	Supply current(1)	MCU @ 2MHz, transceiver in state TRX_OFF		3		mA
7.3.3	Supply current(1)	MCU @ 16MHz (int. RC 32MHz), transceiver in state TRX_OFF		15		mA

No.	Parameter	Condition	Minimum	Typical	Maximum	Unit
7.3.4	Supply current(1)	MCU @ 16MHz (int. RC 32MHz), transceiver in state RX_ON		28		mA
7.3.5	Supply current(1)	MCU @ 16MHz (int. RC 32MHz), transceiver in state BUSY_TX		26		mA

Note: 1. Measurement results with diode D1 removed.

8.4 Duty cycle requirements

Table 8-4. TX operating condition.

No.	Parameter	Condition	Minimum	Typical	Maximum	Unit
7.4.1	TX Duty Cycle OQPSK(1)	over 100ms IEEE802.15.4 channel 26			31	%

Note: 1. To ensure FCC compliant operation in IEEE802.51.4 channel 26, the TX duty cycle has to be equal or below the specified maximum value under normal and extreme conditions. The duty cycle for other channels is not restricted.
For further details refer to VNR-E33SD-X5B-00 FCC test report.

Appendix A. Abbreviations

AD	-	Antenna diversity
CRC	-	Cyclic redundancy check
ETSI	-	European Telecommunications Standards Institute
FCC	-	Federal Communications Commission
ISM	-	Industrial, scientific and medical (frequency band)
MAC	-	Medium access control
MCU	-	Microcontroller
PER	-	Packet error rate
R&TTE	-	Radio and Telecommunications Terminal Equipment (Directive of the European Union)
RF	-	Radio frequency
RX	-	Receiver
SMA	-	Sub-miniature-A (connection)
SPI	-	Serial peripheral interface
TX	-	Transmitter

Appendix B. Radio certification

The device REB233CBB Module, consisting of:

1. Radio PCB (REB233SMAD v8.1.0) assembled with
2. Two 2.4GHz Omni Rubber Antennas M35-S [2], mounted on a
3. Microcontroller PCB (Controller Base Board (CBB)), which hosts an application firmware available with
4. Atmel AVR2025: IEEE 802.15.4 MAC Software Package [7],

Only this combination of components and assembled as described in Section 4 has received regulatory approvals for modular devices in the United States and European countries. The REB233CBB Module is shown in Figure 1-1.

B.1 United States (FCC)

Compliance Statement (Part 15.19)

The device complies with Part 15 of the FCC rules. To fulfill FCC Certification requirements, an Original Equipment Manufacturer (OEM) must comply with the following regulations:

- The modular transmitter must be labeled with its own FCC ID number, and, if the FCC ID is not visible when the module is installed inside another device, the outside of the device into which the module is installed must also display a label referring to the enclosed module
- This exterior label can use wording such as the following. Any similar wording that expresses the same meaning may be used

Contains FCC-ID: VNR-E33SD-X5B-00
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Use in portable exposure conditions (FCC 2.1093) requires separate equipment authorization. Modifications not expressly approved by this company could void the user's authority to operate this equipment (FCC Section 15.21).

Compliance Statement (Part 15.105(b))

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna
- Increase the separation between the equipment and receiver
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected
- Consult the dealer or an experienced radio/TV technician for help

Warning: **IMPORTANT FCC NOTICE to USERS**

Changes or modifications not expressly approved by this company could void the user's authority to operate the equipment.

B.2 Europe (ETSI)

If the device is incorporated into a product, the manufacturer must ensure compliance of the final product to the European harmonized EMC and low-voltage/safety standards. A Declaration of Conformity must be issued for each of these standards and kept on file as described in Annex II of the R&TTE Directive.

The manufacturer must maintain a copy of the device documentation and ensure the final product does not exceed the specified power ratings, and/or installation requirements as specified in the user manual. If any of these specifications are exceeded in the final product, a submission must be made to a notified body for compliance testing to all required standards. The "CE" marking must be affixed to a visible location on the OEM product. The CE mark shall consist of the initials "CE" taking the following form:

- If the CE marking is reduced or enlarged, the proportions given in the above graduated drawing must be respected
- The CE marking must have a height of at least 5mm except where this is not possible on account of the nature of the apparatus
- The CE marking must be affixed visibly, legibly, and indelibly

More detailed information about CE marking requirements you can find at "DIRECTIVE 1999/5/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL" on 9 March 1999 at section 12.

B.3 Approved antenna

The device has been tested and approved for use with the antenna type listed below. The device may be integrated with other custom design antennas which OEM installer must authorize with respective regulatory agencies. The used antenna is to be connected to the Radio PCB via an SMA connection.

Table 8-5. Approved antenna.

Manufacturer	Description	Model	Frequency	Connector
TEKFUN Co.	¼-wave swivel SMA Male antenna	M35-S	2400MHz	Male SMA

Appendix C. References

[1] IEEE Std 802.15.4™-2011: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)

[2] M35-S; Swivel SMA Male antenna for 2.4GHz; Technical specification; http://www.tekfun.com.tw/product.php?mode=show&cid=28&pid=255; TEKFUN CO., LTD.

[3] AT86RF233; Ultra-low Power, 2.4GHz Transceiver for ZigBee, IEEE 802.15.4, 6LoWPAN, RF4CE, SP100, Wireless HART and ISM Applications; Datasheet doc. no. 8351; Atmel Corporation

[4] Atmel ATxmega256A3; High-performance, Low-power 8/16-bit AVR XMEGA Microcontroller; datasheet; rev. 8068P – 02/10; Atmel Corporation

[5] FCC Code of Federal Register (CFR); Part 47; Section 15.35, Section 15.205, Section 15.209, Section 15.232, Section 15.247, and Section 15.249. United States.

[6] ETSI EN 300 328, Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Wideband Transmission Systems; Data transmission equipment operating in the 2.4GHz ISM band and using spread spectrum modulation techniques; Part 1-3.

[7] Atmel AVR2025: IEEE 802.15.4 MAC Software Package – User Guide; Application Note doc. no. 8412; Atmel Corporation

[8] USB Level Shifter Stick Basic; datasheet; 03/12; Dresden Elektronik Ingenieurtechnik GmbH

Appendix D. Revision History

Version	Description
42156A	Initial revision

Atmel | Enabling Unlimited Possibilities®

Atmel Corporation
1600 Technology Drive
San Jose, CA 95110
USA
Tel: (+1)(408) 441-0311
Fax: (+1)(408) 487-2600
www.atmel.com

Atmel Asia Limited
Unit 01-5 & 16, 19F
BEA Tower, Millennium City 5
418 Kwun Tong Road
Kwun Tong, Kowloon
HONG KONG
Tel: (+852) 2245-6100
Fax: (+852) 2722-1369

Atmel Munich GmbH
Business Campus
Parkring 4
D-85748 Garching b. Munich
GERMANY
Tel: (+49) 89-31970-0
Fax: (+49) 89-3194621

Atmel Japan G.K.
16F Shin-Osaki Kangyo Bldg.
1-6-4 Osaki, Shinagawa-ku
Tokyo 141-0032
JAPAN
Tel: (+81)(3) 6417-0300
Fax: (+81)(3) 6417-0370