EMBee wireless modems

- ZigBee transmission protocol, EM250 chip from EMBER
- It is fitted with 4 operating systems: ZigBee stack, OS Coordinator, OS Router, OS sleep device
- Automatic reservation of network coordinator by router in case of failure of the main coordinator
- Easy to integrate with help of AT-Command interface
- Self-forming, self-healing after device initialization
- Excellent noise and soft-error immunity of ZigBee network
- Total number of 65 000 operating devices in ZigBee network

User Guide v2.01
EMB-250-100UI-003
EMB-250-100CI-002

Contents

1. General features of the wireless modem

1.1 Key Features

High performance at a low cost

EMBee:

- Transmission range in the city, building: 80m
- Open-air transmission range: 1800m
- Transmit power: 100mW (20 dBm)
- Receiver Sensitivity: -89 dBm

Advanced Networking & Security

EMBee:

- Retries and Acknowledgement of transmission
- Each channel has 65 000 unique available network addresses
- The topology of Mesh Network is supporting
- 128-bit Encryption

Low power consumption

EMBee:

- current RX: 35,5mA (3.3V)
- current TX at the moment of terminal polling (short pulse 3 mS): 165mA±10% (3.3V)
- Sleep current: 1 uA

Easy-to-Use

EMBee:

- Self-forming of Mesh Network (coordinator->all devices; coordinator ->device; device ->coordinator)
- Seif-reorganize of network by replacing a coordinator (this task can take any router)
- Self-healing of the drop-out network devices
- Supporting of various device's types (easy change by AT-command):
  -coordinator
  -router
  -sleep device
  -mobile device (sleep device is relocatable)
- Supporting up to 6 sleep devices (mobile devices) by a coordinator and each of routers
- Receiving information about connected devices in a network and their connections
- The possibility of obtaining a loop back from any of devices
- The small dimensions
- AT and API command modes for configuring the parameters of the wireless modems and data transmission

1.2 EMB-250-100CI-002 Modem Features

Table 1. EMBee Modem Features

Features	EMBee
Performance	
Transmission range in the city, building (Pout=100mW)	up to 80 m
Open-air transmission range (Pout=100mW)	up to1800 m
The maximum equivalent isotropic radioted power in the band selected channel of 5 MHz within the range of 2400-2438 MHz (software adjusted)	100 mW (20 dBm)
Network speed	250 Kb/s
Baud rate in Mesh network	4 800 Baud
Command line interface speed (software adjusted)	1200-38400 bit/s
Sensitivity of a receiver	-94 dBm (1% PER)
Energy Consumption	
Power supply	2,1 – 3,6 V
Current transmission (pulse 3 мs.) (Pout=100мВт)	165mA±10%
Current expectations/current reception (average)	36 mA±10%
Power-down (sleep) current	1 uA
General Performances	
Frequency range	2400-2438 MHz
Dimensions (mm)	24,00 x 47,60
Operating temperature range	-40°C to 85°C
Antenna type EMB-250-100CI-002	Integrated on board SMD ceramic antenna
RF connector type EMB-250-100UI-003	U.FL for external antenna
EMBEE network Parameters and Security	
Operating network	Mesh network: coordinator –all devices; coordinator – device; device-coordinator: advanced network encryption
Type of modulation	O-QPSK
Number of channels	16
Number of operating devices	65000
Transmission types	Via network (PAN ID a 128-bit password), channel or command line dentifier

1.2 Pin assignments

Tabl 1.2. Pin assignments for EMBee modem (The data transmited low level are underlined)

Pin#	Name	Direction	Description
1	VCC	-	Power supply (3.3V)
2	nDOUT	Output	UART Data Out
3	nDIN	Input	UART Data In
4	DIO8/NW_READY	Output/Input	Digital port 8/ network and data transmission availability
5	RESET	Input	Module Reset
6	PWM0/RSSI	Input/Output	Digital port 10, PWM output channel 0 or received signal of strength indication
7	PWM1	Input/Output	Digital port11, PWM output channel 1
8	DIO9	Input/Output	Digital port 9
9	SLEEP_RQ	Input	Pin Sleep Control
10	GND	-	General
11	DIO4	Input/Output	Digital port 4
12	DIO7/CTS	Input/Output	Digital port 7 or CTS signal transmission control serial data
13	nSLEEP_OUT	Output	The indicator of mode status "sleep" of the wireless modem
14	-	-	Reserve
15	DIO5	Input/Output	Digital port 5
16	DIO6	Input/Output	Digital port 6
17	AD3/DIO3	Input/Output	Analog input 3 or Digital port 3
18	AD2/DIO2	Input/Output	Analog input 2 or Digital port 2
19	AD1/DIO1	Input/Output	Analog input 1 or Digital port 1
20	AD0/DIO0	Input/Output	Analog input 0 or Digital port 0

Design Notes:

1. Minimum connections: VCC, GND, DOUT and DIN.
2. Unused pins should be left disconnected

1.3 AC Electrical Performances

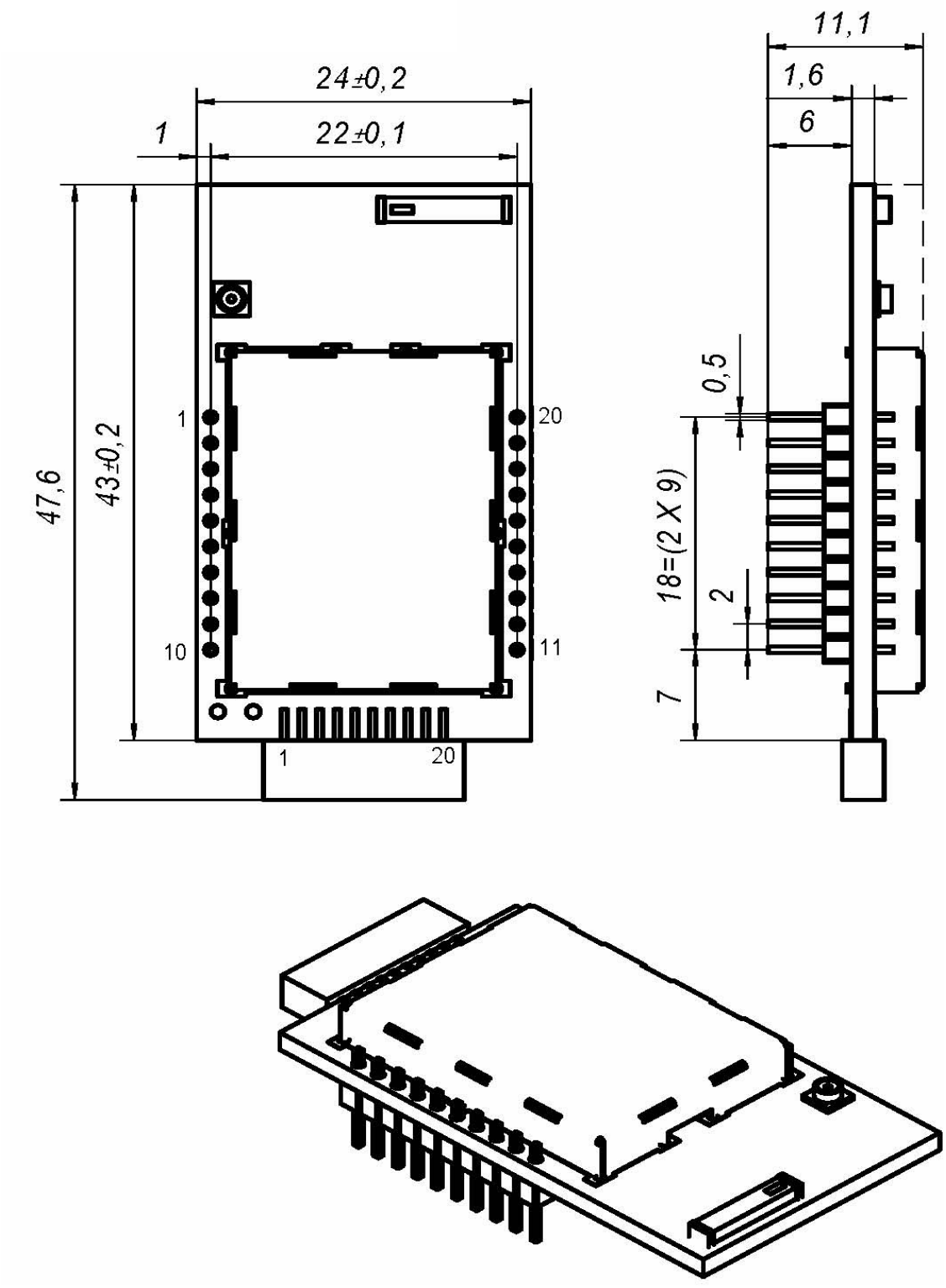
Table 1.3. Electrical Characteristics of DC current

Symbol	Parameter	Condition	Min.	Average	Max.	Unit
V_{IL}	Input Low Voltage	All Digital Inputs	-	-	0,2*VCC	V
V_{IH}	Input High Voltage	All Digital Inputs	0,8*VCC	-	VCC	V
V_{OL}	Output Low Voltage		0	-	0,18*VCC	V
V_{OH}	Output High Voltage		0,82*VCC	-	VCC	V
II_{IN}	Input Leakage Current	V_{IN}=VCC or GND, all inputs	-	-	0,5	uA
TX	Transmit Current	VCC=3,3V	-	35,5	-	mA
RX	Receive Current	VCC=3,3V	-	35,5	-	mA
PWR-DWN	Sleep current		-	1	-	uA

Table 1.4. ADC Characteristics (Analog to Digital converter)

Symbol	Parameter	Condition	Min.	Typ.	Max	Unit
AV_{REF}	Reference Supply Current	-	-	-	1,2	V
RES	Number of digits	-	-	12	-	bit
I_{REF}	Consumption Current	Affiliate	-	1	-	mA
		Mode "sleep"	-	-	1	uA

1.4 General design

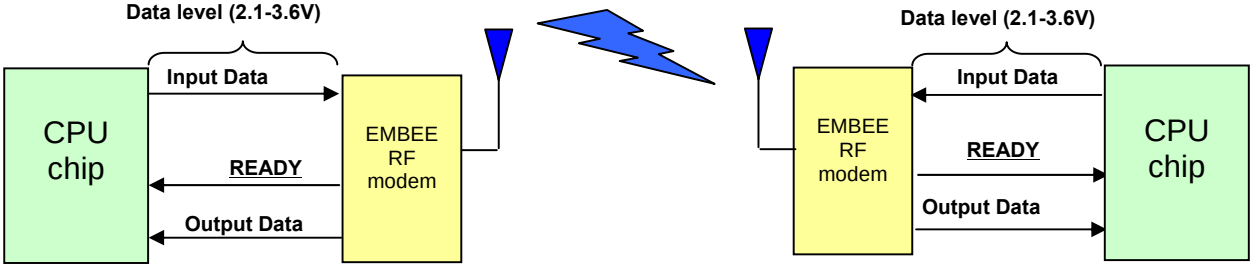


2. Functional operation of a wireless modem

2.1. Serial Interface

UART Data Flow

Devices that have a UART interface can connect directly to the pins of the wireless modem as shown in the figure below Fig. 2.1.



The wireless modem is controlled by CMOS logic levels 2.1 - 3.6 V. The converter MAX3232 type or similar type is required in order to connect the wireless modem to the COM- port of the PC.
Data enters to the modem through the DI pin as a serial code with an Idle level log. "1." Each data byte consists of a start bit and a stop bit. Least significant bit transfers by the first, it follows immediately after the start bit.

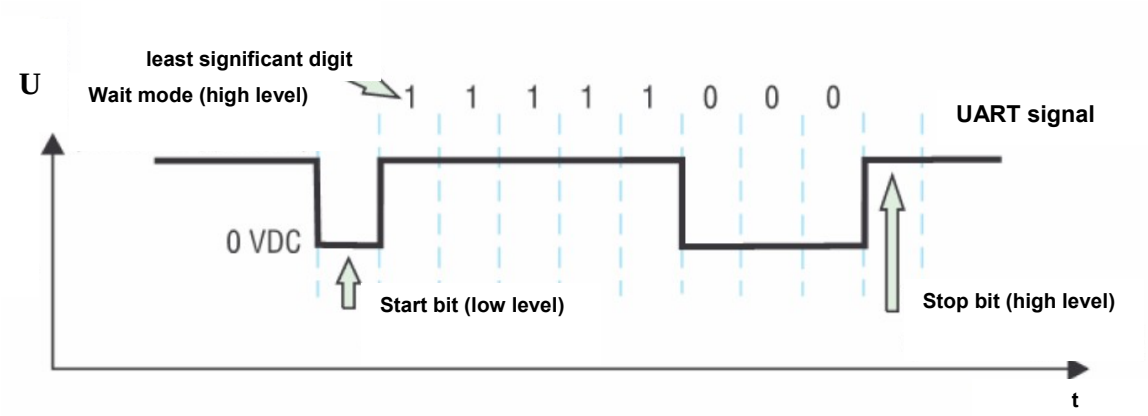


Figure 2.2. Transfering of 0x1F byte to the EMBee wireless modem

For a successful data transfer through the serial interfaces both UART modules of a receiver and a transmitter must be configured with the same parameters.

2.1.1. Flow control

Input Buffer

When serial data enters to the wireless modem through the DI pin, the data is stored in the DI Buffer until it can be processed. The transmission is delayed if, for examle, at the same time, the radio data is being received or a previous transfer is not complete.
The maximum size of a receive buffer consists 246 bytes.

Hardware flow control (nREADY - availability for receive)

For hardware transmission control it is necessary to put a nREADY signal through a DIO8 pin or a DIO7 pin with using such commands as a C8 =1 or C7 = 1 (see below Tabl.3.7). Usually, the DIO7 is used to control the nREADY through a COM port on a debug kit. The algorithm of the nREADY is next. The nREADY = 0 indicates availability to receive a data in module. After the data has received into a input buffer it is necessary to wait for removal of the nREADY = 1 which confirm the start of the RF data transmission. An appearance of the nREADY = 0 signal indicates the end of the data transmission; this signal gives a possibility of sending a next packet.
It is possible to refuse the transmission control if the speed is reduced to the value when the data is transmited faster through the radio channel than a receive buffer is filled.
Overflowing of the buffer will be able to occur if the wireless modem receives a long and a steady data stream throught a radio channel. In this case, the rest of the data which is transmitted through the DI pin will be lost after the buffer has been fulled.

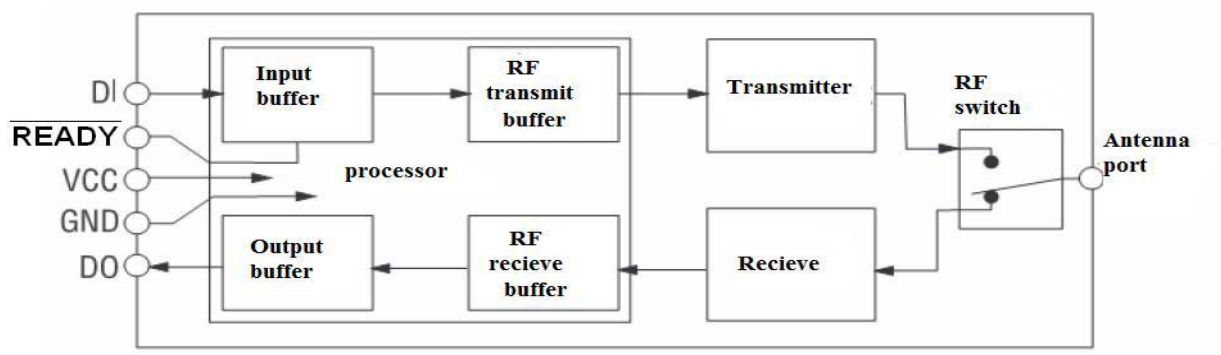


Figure. 2.3. The internal structure of the EMBee module

DO (Data Out) Buffer

When radio data is received, the data enters to the DO buffer and is sent out to the serial port to a host device.

2.1.2. Transparent Mode

It is used by default (AP = 0) (see Table below. 3.5.). Under this mode, all data received through the DI pin is queued up for RF transmission. All accepted radio data is sent to the DO pin.
When a threshold of RO parameter (Packetization Timeout) is exceeded, the wireless modem is trying to start a radio broadcast. If the wireless modem can not immediately start the transfer (for example if it is already receiving radio data), the serial data will be stored in the input buffer.The data is being packed and it is being sent at any RO timeout or when 246 bytes are obtained (maximum packet size).
The wireless modem works, as described above, if the command sequence is not founded. The command sequence consists of three copies of the characters of the command (CC option, "+ ++" by default) (see below p.2.2.4.). The command sequence switches the wireless modem into the command mode. Exceeding the time between the characters its define as data (GT parameter).
In the transparent mode, a fixed packet in a DN parameter (Destination Node) is always sent from a coordinator to an addressee. DN ='' (default) defines a broadcast addressing. All other devices always send the packet to a coordinator. Under the transfer NT parameter always defines a maximum waiting time of a delivery packet confirmation and then it registers the norm of a delivery packet and an error of non-delivery (see Table below. 3.3.). In this case, on the DOpin nothing is given (only a packet from the destination). Thus in the transparent mode to determine a delivery packet it is possible only with help the a nREADY signal (in case of an error, it is always set), which must be established before the set time in a NT parameter. Otherwise, it will be shown that the packet is not delivered.

2.1.3. API Operation

API (Application Programming Interface) is an alternative to the transparent mode (AP=1).
The frame-based API extends the level to which a host application can interact with the networking capabilities of the wireless modem.

Under API operation, it is possible to send data frames to wireless modems that contain adress and payload information instead of using command mode.

API Operation option facilitates many operations such as the examples cited below:

- transmitting data to multiple destinations without entering command mode
- receive success/failure status of each transmitted RF packet
- identify the source address of each received packet
- read and write remotely into ports of the wireless modem, interview ADC channels, control the PWM channel

API packet format is represented below (Table 2.1.)

Table 2.1. API packet format

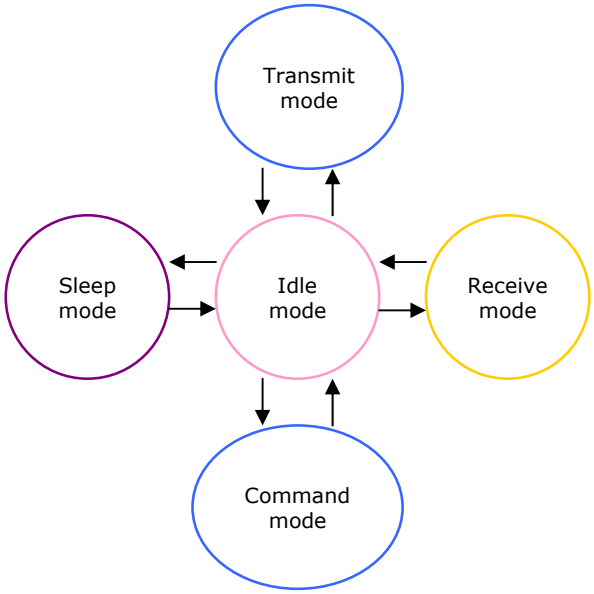
Mode	Sending packet (DI pin)	Answer from the wireless modem (DO pin)
The packet data transfer from a coordinator	DN<CR><LF>[Packet Data]	OK<CR><LF> - standard ERROR<CR><LF> - fault
Receive the packet data to a coordinator	-	NI<CR><LF>[Packet Data]
Record to an external device the remote wireless modem from the coordinator.	(DN)(space)(DX,PX)<CR><LF>Data	OK<CR><LF> - standard ERROR<CR><LF> - fault
Read an external device of the remout wireless modem from the coordinator	(DN)(space)(DX,PX)<CR><LF>	OK<CR><LF> - standard ERROR<CR><LF> - fault if OK, after (NI)(space)(DX,PX)<CR><LF>Data <CR><LF>
The packet data transfer to the coordinator	<CR><LF>[Packet Data]	OK<CR><LF> - standard ERROR<CR><LF> - fault
Receive packet data from the coordinator	-	<CR><LF>[Packet Data]
Record in an external device a remote coordinator	(space)(DX,PX)<CR><LF>Data	OK<CR><LF> - standard ERROR<CR><LF> - fault
Read an external device of remote coordinator	(space)(DX,PX)<CR><LF>	OK<CR><LF> -standard ERROR<CR><LF> - fault если OK, затем (space)(DX,PX)<CR><LF>Data <CR><LF>
Automatic output of an external devices into the coordinator	-	(NI)(space)(DX,PX)<CR><LF>Data <CR><LF>

Automatic output of an external devices from the coordinator	-	(space)(DX,PX)<CR><LF>Data <CR><LF>

Notes:
DN - Destination Node
NI - Node Identifier
DX, PX – adresse of the external devices of D0-D9, P0, P1
Data – byte or word which means data
Packet Data – packet of data
<CR><LF> - line feed, carriage return, 0x0D, 0x0A characters
NT parameter specifies the timeout of delivery packet to the addressee, non-delivery of the package - "ERROR".

2.2. Modes of Operation

Embee wireless modems operate in 5 modes.



2.2.1. Idle Mode

When not receiving or transmitting data, the wireless modem is in Idle Mode.
The other modes of operation under the following conditions:

- Transmit Mode (serial data is received in the DI Buffer)
- Receive Mode (Valid RF data is received through the antenna)
- Sleep Mode (Sleep Mode condition is met)
- Command mode (Command Mode Sequence is issued)

2.2.2. Transmit/Receive Modes

When serial data is received and is ready to packetization, the wireless modem is ready to transfer a packet on the air, the wireless modem transfers from the Idle mode into the thansmit mode. From a coordinator the packet forwards to the destination address. A destination address is determined by DN command parameter within the transparent mode. The destination address is defined in a packet in accordance with the API format within the API mode. Each module must be assigned an address that is specified by the NI command in the network. All packets are sent from a device to a coordinator regardless of destination.

If the transfer does not broadcast (DN command option is put), the wireless modem will wait for an acknowledgment from the destination device. If an acknowledgment is not received, confirmation will be registered the transfer error. If radio packet is received and an address corresponds to a NI command, the data from the receive buffer are issued through the serial port.

Remote mode access to external devices

It is necessary to use API mode (AP = 1) for reading and recording in the external device of the remote wireless modem. In the out packet an address of the wireless modem (DN), the address of the external device (D0-D9, P0, P1) and the transmitted data in accordance with the API format is indicated in the out packet.
The D0-D9 addresses are in accordance with the DIO0-DIO9 ports, the D0-D7 addresses can be in accordance with the ACP channels. The P0, P1 addresses are in accordance with the ports or SHIM0, SHIM1 such pins as PWM1 and PWM1. Howevere the receiving pins (C9 = n, CP0-CP1 = n) should be configured previously where «n» sets the operating mode of the pin. After saving of the configuration, the pins of the external device have been switched to the established regime.

The automatic output mode of the external devices on the remote devices

For the automatic output all wireless modems have to be put under the API (AP = 1) mode. Under this mode, a DIO0-DIO9, a PWM0, a PWM1 pins are configured previously, they can be transmitted on the UART of the remote device (it is addressed in the DN parameter with a set period in IR parameter). In this case, IU parameter should be set 1. IR = 0 it disconnects the automatic outputs mode.

In sleep devices, in this mode, it is necessary to take account of a device which is in a disabled state a certain time and only displays the data at the time of awakening.
Since the device activity can vary and the number of awakenings is determined experimentally before the automatic output.

The virtual display mode of ports

The wireless modems must be switched to the output automatic mode for the virtual display of ports. The outputs on the receiving wireless modems must be configured as outputs, and outputs on the transmitting wireless modems as inputs. The IU (IU = 0) parameter determines a virtual display mode of ports. The IR parameter determines a period of the virtual display. IU, IR parameters set on the transfer module. DN parameter determines a receiver address. The full-duplex display mode can be used when the inputs as outputs are displayed on both wireless modems.Under the virtual display all DIO0-DIO9 pins display.ACP channels AD0, AD1 display as PWM0, PWM1.

2.2.3. Sleep mode

Sleep Modes enable the module to enter states of low-power consumption when not in use.
In order to enter the sleep mode, it is necessary to configure the wireless modem as a sleep device (AD = E, AD = M). After connecting to network the wireless modem enters a low power consumption with a period of SP awakening, confirming this mode by voltage at the low level nSLEEP_OUT output. Mobile devices (AD = M) are designed for moving objects, and can only operate in a cyclic mode. If your mobile device is not applied to the network within 50 seconds the network its strikes out from their tables and then the mobile device will be restored. The 0xFFFF SP value translates the module into the permanent sleep mode. The output from the sleep mode is implemented by applying a positive drop to the SLEEP_RQ output. After awakening, the module accepts or displays messages and plunges into a sleep again. The nDIN pin is used as well in order to wake up the module. After the issuance of confirmation "WAKE UP» through a nDOUTpin the module goes into adle mode for some time and then switches back to a sleep mode.

2.2.4. Command mode

To modify or read module parameters, the module must first enter into the command mode, a state in which incoming characters are interpreted as commands. To enter AT command mode is necessary to send the 3-charachter command sequence "+++". After the issuing an "OK" the wireless modem goes into the command mode.

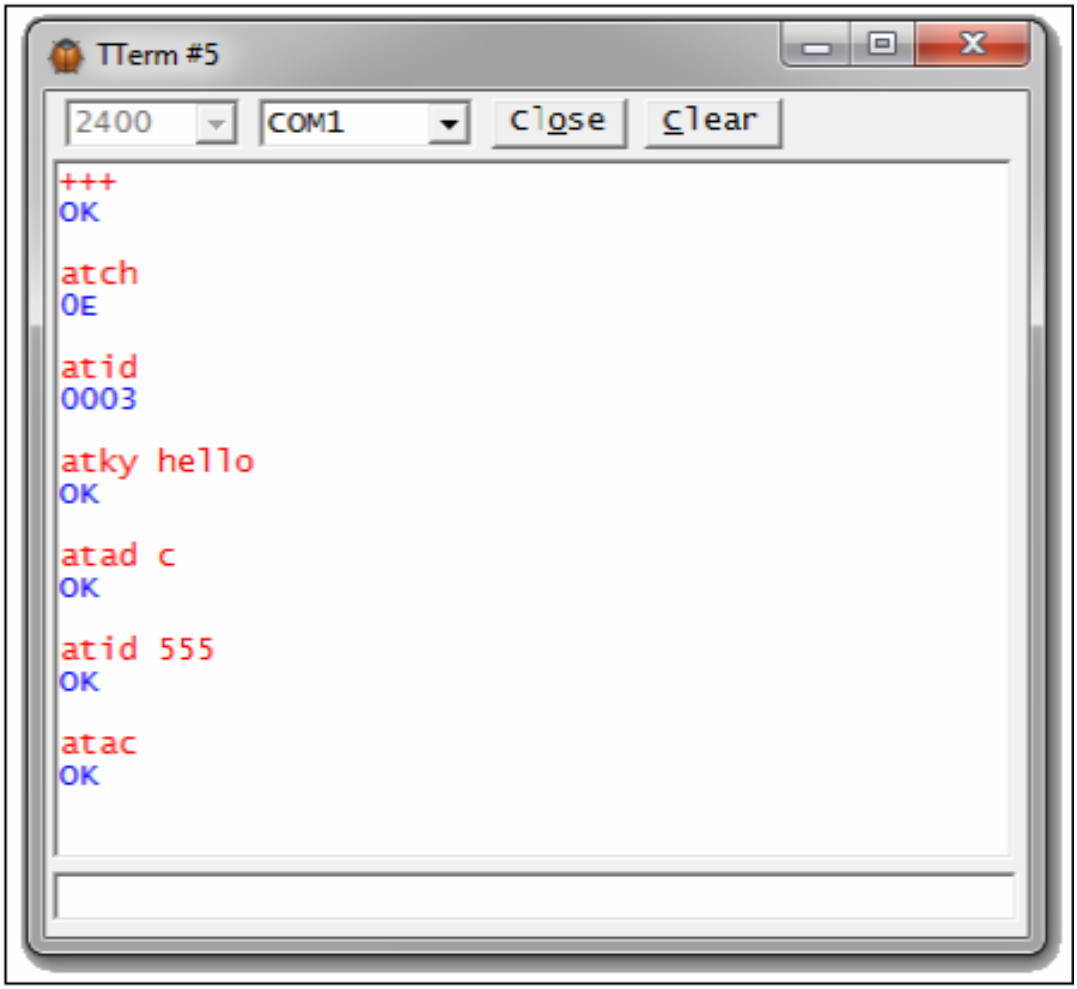
If the time between each characters sequence "+++" is greater than the time set in GT parameter (default seconds), the sequence is perceived as the data. Characters of the command sequence can be changed by using a CC command.

Each AT command irepresents a string text starts with "AT". The following is the command code, the space, the command parameter and the character "carriage return "(<CR>, code 0x0D), "turn a new line" (<LF>, code 0x0A)

(Table 2.2). For example, the command that changes the number of a «0x10» radio channel will look like this: ATCH 10 <CR> <LF>. In order to save changed parameters of the wireless modem WR (Write) write command write is used in nonvolatile memory. If the WR command is not used the previous parameters will be restored after switching off and power re-supply. At first, each deliver command is recognized by the module and then executed. In case of a successful execution the wireless modem will give the string "OK" through DO pin. If the command doesn't work the message «ERROR» will enter an external microcontroller. The wireless modem goes out from the command mode with «ATCN» command. Under the command mode all characters can be put either upper or lower register of the keyboard. The wireless modem responds to numerical values of sexadecimal number and decimal number of the upper register and values of the characters of the lower register

Table 2.2. Example of AT-command

Sending AT-command	Answer from the wireless modem
+++	OK <CR><LF> Enter the command mode
ATCH<Enter>	{the current value} <CR><LF> (to read the CH value CH) <CR><LF>
ATCH 10<Enter>	OK <CR><LF (to change the value from CH to 0x10)
ATWR<Enter>	OK <CR><LF> (to write in the nonvolatile memory)
ATCN<Enter>	OK <CR><LF> (to exit from the command mode)



2.3. Networking Modes

2.3.1. Unicast Mode

Under this mode all packets are sent from a coordinator to an addressee in the transparent mode which is set by DN command parameter, and the API command at the specified address in the API packet in accordance with the API format. Under the transparent mode a delivery packet sets the ready to DIO8 (C8 = 1) or DIO7 (C7 = 1) zero level earlier the time than in NT parameter. Under the API command the delivery packet returns through a DO <OK> pin, without the deliver <ERROR>. Under these conditions the NT parameter determines the maximum waiting time of delivery packet. The packet is always sent to the coordinator regardless of destination.

2.3.2. Multicast Mode

Under the multicast mode, the packets are always sent from a coordinator to all devices in the network without waiting for delivery with the parameter DN ='' parameter or an addressee with an empty string. Under a synchronous transfer the MD command parameter determines the delay between the packets for successful delivery to all subscribers.

3. Module Configuration

Configuring the wireless modem (changing settings) can be made by filing a command sequence to the DI pin. Each wireless modem in the network must have the same version of firmware.

3.1. Command Table

EMBee radio modems operate numeric values in hexadecimal. The PL, DB commands use a negative decimal values. Description of the commands is grouped by a category and is contained in the table. 3.1.-3.9. Hexadecimal values in the tables are defined "0x" prefix.

Table 3.1. Special destination

AT command	Name and description of the command	Device type*	Accepting values	Default value
WR	**Write**. Write parameter values to non-volatile memory so that the parameter modifications will be preserved after the power-up or reset. Note: As soon as the WR command is issued, no additional charecters should be sent until the the "OK" response is received.	CREM	-	-
RE	**Restore Defaults.** Restore wireless modem parameters to factory defaults.	CREM	-	-
FR	**Software Reset.** Responds immediately with an "OK" then performs a hardware reset of this device about in 100ms.	CREM	-	-
NR	**Network Reset.** In the coordinator it restarts the network with a delay which is set in the parameter. It returns an "OK" after a delay. The delay is necessary for sleep devices, which are restarted after awekening if there is no network. In other devices running the same function as FR.	CREM	0 - 0xFFFE [x 1 sec]	-

*** CREM – Coordinator, Router, End device, Mobile device.**

Table 3.2. Addressing commands

AT command	Name and description of the command	Node type*	Parameter Range	Default
MY	**16-bit Network Address.** Get the 16-bit network addresse.	CREM	0 - 0xFFFE	0xFFFE
MS	**16-bit Source Network Address.** Receive the 16-bit of the wireless modem	CREM	0 - 0xFFFE	-
SH	**Serial Number High.** Read high 32 bits of the unique 64-bit address of the wireless modem.	CREM	0 - 0xFFFFFFFF [read-only]	factory-set
SL	**Serial Number Low.** Read low 32 bits of the unique 64-bit address of the wireless modem.	CREM	0 - 0xFFFFFFFF [read-only]	factory-set
NI	**Node Identifier.** Stores a string identifier. Register only accepts ASCII data. A string can not start with a space. A carriage return ends the command. The command will automatically end when maximum bytes for the string have been entered. This string is returned as part of the ND command. This identifier is also used with a command DN (the destination).	CREM	32-Byte printable ASCII line #0-removes a line	-
DN	**Destination Node.** Store a string identifier of the destination node. Register only accepts ASCII data. The string can not start with a space.	C	32-Byte printable ASCII string #0-removes a line	-
SN	**Source Node Identifier.** Store a string identifier of the source. The regisetr only accept ASCII data.	C	32-Byte printable ASCII line	-

*** CREM – Coordinator, Router, End device, Mobile device.**

Table 3.3. Network command

AT command	Name and description of the command	Node type*	Parameter Range	Default
CH	**Channel.** Set / Read the channel number used for transmitting and receiving. Uses 802.15.4 channel number.	CREM	0x0B-0x1A *(EMBEE)*	0xF
ID	**PAN ID.** Set / read the ID of the personal area network (PAN).	CREM	0 - 0x3FFF	0x1234 (4660d)
KY	**AES Encryption Key**. Installation of a 128-bit AES (Advanced Encryption Standard) key to encrypt / decrypt data. KY register is not available for reading. The KY command is used to set the 128-bit AES (Advanced Encryption Standard) key for encrypting/decrypting data. Ones set, the key cannot be read out of the module by any means.	CREM	0 - (any 16-Byte value) #0-removes a line	0x0
NT	**Node Discover Timeout.**Set / Read a maximum waiting time of delivery data to the node.	CREM	0 - 0xFFFFFFFF [x 1 msec]	0x1770 (6000d)
ND	**Node Discover.** Discover and reports all wireless modems found. The following information is reported for each modem discovered: **DEVICE_TYPE**(1 Byte: "C"=Coord, "R"=Router, "E"=End Device, "M"=Mobile Device) **: EUI64, NI**<CR><LF> when **EUI64** = **SH** + **SL** The command is waiting for a response from the device indefinitely (to enter any commands).	C	-	-

LB	**Loop Back.** The register is only available by appointment. DN is equal to an empty string to enable / disable the loop back mode on all devices on the network. Under broadcast sending (DN =''') the reponse only returns the addressed device. The format of the sending packets: Address (null terminated string) _Data. Fixed DN enables / disables the loop back mode only for the addressed device. Returning data in any format.	C	0 – 1 0 – loopBack Off 1 – loopBack On	0
AD	**Association Device**. Set/Readthe the association device.	CREM	char DEVICE_TYPE "C"=Coord "R"=Router "E"=End Device "M"=Mobile Device	"R"
RN	**Ready Network.** Read the ready network.	CREM	0 – 1 (read only) 1 - Ready	0
MD	**Multicast Delay.** Set / read the delays between frames for multicast sending in the network.	C	0 - 0xFF (x 1sec)	0
PT	**Poll Times**. For the sleep device: The time between the poll times	CREM	1 - 0xFFFF (ms)	0x3E8 (1000ms)

*** CREM – Coordinator, Router, End device, Mobile device.**

Table 3.4. Radio connection commands

AT command	Name and description of the command	Node type*	Parameter Range	Default
PL	**Power Level.** Select/ Read the power level at which the wireless modem transmits conducted power.	CREM	3 – (-43)dBm EMBee)	3

Table 3.5. Serial interfacing comands

AT command	Name and description of the command	Node type*	Parameter Range	Default
BD	**Interface Data Rate.** Set/ read the serial inteface data rate for communication between the wireless modem serial port and host. Setting after the wireless modes saved and restarted.	CREM	0 - 7 (standard baud rates) 0 = 1200 bps 1 = 2400 2 = 4800 3 = 9600 4 = 19200 5 = 38400 6 = 57600 7 = 115200	3 (9600)
RO	**Packetization Timeout.** Set / read the delay time which is required before the transmission. Set to zero in order to transmit the characters as soon as they arrive on the radiomodem instead of the buffering them into one package.	CREM	0 - 0xFFFF [x character times ms]	20
AP	**API Enable.**Set API command.	CREM	0 - 1 0 = Disabled 1 = API enabled	0

Table 3.6. Sleep Commands

AT command	Name and description of the command	Node type*	Parameter Range	Default
SP	**Sleep Period.**This value determines how longthe end device will sleep at a time. The wireless modem wakes up briefly and then performs the active task, if it was installed. A value of 1 = 1/4 c. The value 0xFFFF translates the wireless modem into the permanent sleep mode. Exit from thepermanent sleep turns by nDIN SLEEP_RQ pins.	EM	1 - 0xFFFF	0xC (3s)

*** EM – End device, Mobile device.**

Table 3.7. Commands input-output

AT command	Name and description of the command	Node type*	Parameter Range	Default
C0-C9	**DIO0–DIO9 Configuration.** Alternate functions: DIO3 (CTS), DIO8 = 1 - network readiness, willingness to deliver data DIO0-DIO3 = 2 - ADC	CREM	0 = Disabled 1 = Alternative function 2 = ADC 3 = DI 4 = DO low 5 = DO high	0
CP0	**PWM0 Configuration.** Set / read PWM0 mode output. Parameters of PWM - 3600mks period, the positiv duration is equile: - The PWM pin = (3600/65536) * Data_PWM (ms)	CREM	0 = Disabled 1 = RSSI (-25..-91dBm) 2 = PWM Output 3 = DI 4 = DO low 5 = DO high	0
CP1	**PWM1 Configuration.** Set / read PWM1 mode pin. Parameters of PWM –similarly to PWM0.	CREM	0 = Disabled 1 – Reserved 2 = PWM Output 3 = DI 4 = DO low 5 = DO high	0
IU	**I/O Output Enable.** Disabling / Enabling the automatic output to the serial receiver port. Under output disable mode switching the mode of the virtual display ports – the input and the output data of the transmitter are displayed on the receiver.	CREM	0 - 1 0 = Disabled 1 = Enabled	1
IR	**Sample Rate.** Set / read period of an automatic output on the receiver of inputs set which are included at the transmitter. 0 disconnect the automatic output.	CREM	0 - 0xFFFF [x 1 msec]	0

Table 3.8. Diagnostics commands

AT command	Name and description of the command	Node type*	Parameter Range	Default
VR	**Firmware Version.** Read firmware version of the wireless modem.	CREM	0 - 0xFFFF [read-only]	Factory-set
HV	**Hardware Version.** Read firmware version of the wireless modem.	CREM	0 - 0xFFFF [read-only]	Factory-set
DB	**Received Signal Strength.** Read the signal level (in decibels) of the last received packet (RSSI). Returns the absolute value. (For example: 0x58 = -88 dBm). After the DB command the first five minutes after the restart the coordinator with a period of 15 c. Outputing the power of the received signal in dBm RSSI and signal quality LQI (255 - lossless, 0 - maximum number of losses). After five minutes of the withdrawal period is changed to 1 min. After entering anymode of character mode DB mode is terminated.	CREM	(-25) - (-91) dBm [read-only]	-

Table 3.9. Command options

AT command	Name and description of the command	Node type*	Parameter Range	Default
CN	**Exit Command Mode.** Exit the wireless modem from the mode of command.	CREM	-	-
AC	**Apply Changes.** Apply changes to the next parameter value, save the settings in the non-volatile memory and restart the wireless modem.	CREM	-	-
GT	**Guard Times.** Set/ read a safety time for the transition into command mode. If the time between charachters has 3-symbols CC sequence exceeds the time which is set in parameter GT, the sequence is perceived as the data.	CREM	1 - 0x0CE4 [x 1 ms]	0x3E8 (1000d)
CC	**Command Sequence Character.** Set / read the ASCII character, which is used between the safety times in the command sequence (GT + CC + GT). The command sequence from the 3-symbols transfers the wireless modem into command mode. The protection prohibits perceiving 3 symbols of CC in the packet which is being sent as a command sequence.	CREM	0 - 0xFF	0x2B ('+' ASCII)

*Notice
The type of device: C- coordinator, R- router, E- sleep device; M- mobile device

4. ZigBee network formation

ZigBee network consists of one coordinator and one or more routers and / or sleep devices. ZigBee network is created when a coordinator selects a channel and PANS ID (network identifier) to start on. The network is forming automatically under connecting the routers and the end sleep devices to the coordinator (Figure 4.1). If there is not any coordinator in the network the connecting devices are waiting indefinitely for its appearance in the network. If a coordinator is not contacted, any of devices can be switched to the mode of a coordinator. When the coordinator is being replacing, the network is re-forming automatically (at the same time the terminal sleep device must awake, at least, once in order to detect the absence of the coordinator). Dropping out of the network devices reconnect automatically. When the network is formed from all devices, all communication is only laid to the coordinator. The coordinator may contact to any of the devices or the transfer data to all devices on the network (broadcast).

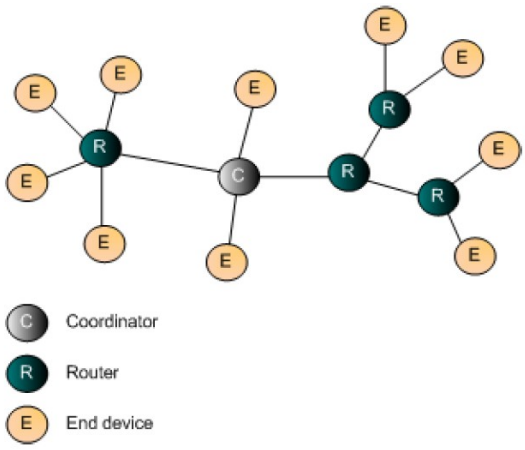


Рис. 4.1. The tree of ZigBee network

When the router or an end sleep device joins the network it is assigned a 16-bit address (MY). Under reconnecting these devices the addresses can change. Therefore, the data transfer is tied to the string identifiers (NI) across the network which the user assigns to the devices. The coordinator has always zero 16-bit address and has a string identifier. Also, each radio has a unique fixed 64-bit identifier (SH, SL).
The end sleep devices always connecte to the routers or the coordinator, though all the links from the end sleep devices are only laid to the coordinator. At the same time the end sleep device is becoming a router's child or coordinator's child. Sending and receiving data in the end sleep device are always working through parent's router or parent's coordinator.
The end sleep devices can be mobile devices. The mobile device performs the same functions as the end sleep device, but it is intended for moving objects. If, within 50 seconds the network does not detect the mobile device, this network will delet from the tables. The end sleep devices support low-power mode and they are designed to use battery power. With help of the ND command it is possible to receive the information about the connected devices to the network and its connections. To protect the network information the network can be formed with KY key. Thus, it is possible to receive a unique network. All devices must have the same CH, ID, KY in the network.

4.1. Coordinator

Coordinator (AD = C) is always online and is designed to form network. After restarting, it allows other types of devices connecte to the network. The coordinator allows up to 65 000 units to connect to the network, of which an unlimited number of routers and up to 6 terminal sleeping devices which are connected to the coordinator. The network is formed with the CH, ID, KY parameters. In addition to the functions of the network formation the coordinator performs all the functions of data transfer and the input-output ports. The coordinator should be provided with a continuous constant voltage.

4.2. Router

Routers (AD = R) is always attached to the coordinator or to other routers, and they are designed for routing data across the network. After restarting, they allow to connect to other routers, or an end sleep device. Each of the routers can be connected up to 6 terminal sleepdevices. The routers are connecting to the network with such parameters as CH, ID, KY. The function of the automatic routing in the routers allows forming the network of unlimited length, and an unlimited range of any tree. In addition to routing networks, the routers perform all functions of the data transfer and input-output ports. The router should be provided with a continuous constant voltage.

4.3. End sleep device

End sleep device (AD = E) always attaches to the coordinator or the routers and they are end device in network which is designed to work with the battery.The end sleep devices are connected to the network with the CH, ID, KY parameters. The function of low-power consumption allows to use the device for a long time the battery power. In the end sleep devices all functions of data transfer and input-output ports are supporting. The mobile sleep device (AD = M) performs all functions of the end sleep device, but it is designed for the moving objects. If the mobile device does not applied to the network within 50 seconds, the network removes it from the tables.

5. Samples of using AT commands

Table 5.1. Configuration of the coordinar

Sending AT-command	**The answer from the wireless modem**
+++	OK <CR><LF> (Enter the command mode)
ATAD C<Enter>	OK <CR><LF> (Set the type of device – coordinator)
ATCH 10<Enter>	OK <CR><LF> (Change the value of CH on 0x10)
ATID 2222<Enter>	OK <CR><LF> (Set the network ID – 0x2222)
ATKY 1234567890<Enter>	OK <CR><LF> (Set the key– 0x1234567890)
ATWR<Enter>	OK <CR><LF> (Write in the nonvolatile memory)
ATFR<Enter>	OK <CR><LF> (Restart the radio modem)

Table 5.2. Configuration of the router

Sending AT-command	**The answer from the wireless modem**
+++	OK <CR><LF> (Enter the command mode)
ATAD R<Enter>	OK <CR><LF> (Set the type of device-router)
ATCH 10<Enter>	OK <CR><LF> (Change the value from CH to 0x10)
ATID 2222<Enter>	OK <CR><LF> (Set the ID of the network – 0x2222)
ATKY 1234567890<Enter>	OK <CR><LF> (Set the key-0x1234567890)
ATNI router1<Enter>	OK <CR><LF> (Assign a string ID –router1)
ATWR<Enter>	OK <CR><LF> (Write in the nonvolatile memory)
ATFR<Enter>	OK <CR><LF> (Restart the radio modem)

Table 5.3. Configuration of the terminal sleeping device sleep

Sending AT-command	**The answer from the wireless modem**
+++	OK <CR><LF> (Enter the command mode)
ATAD E<Enter>	OK <CR><LF> (Set the type of device –sleeping device)
ATCH 10<Enter>	OK <CR><LF> (Change the value from CH to 0x10)
ATID 2222<Enter>	OK <CR><LF> (Set the ID of the network – 0x2222)
ATKY 1234567890<Enter>	OK <CR><LF> (Set the key - 0x1234567890)
ATNI sleep1<Enter>	OK <CR><LF> (Assign a string identifier – sleep1)
ATWR<Enter>	OK <CR><LF> (Assign a string ID –router1)
ATCN<Enter>	OK <CR><LF> (Exit from the command mode)

Table 5.4. Data transfer to a coordinator (transparent mode AP = 0)

Sending data	**The answer from the wireless modem**
	OK <CR><LF> (Network readiness)
12345	(12345 issued in sequence coordinator)

Table 5.5. Data transfer from a coordinator to a router (transparent mode AP = 0)

Sending command/data	**The answer from the wireless modem**
	OK <CR><LF> (Network readiness)
+++	OK <CR><LF> (Entered into the command mode)
ATDN router1<Enter>	OK <CR><LF> (Set the destination node – router1)
ATCN<Enter>	OK <CR><LF> (Exit the command mode)
12345	(The sequence of 12345 is issued in router)

Table 5.6. Broadcast data from acoordinator (Transporent mode AP=0)

Sending command/data	**The answer from the wireless modem**
	OK <CR><LF> (Network availability)
+++	OK <CR><LF> (Enter the command mode)
ATDN #0<Enter>	OK <CR><LF> (Delete the destination node)
ATMD 6<Enter>	OK <CR><LF> (Set the delay between frames 6 seconds)
ATCN<Enter>	OK <CR><LF> (Exit the command mode)
12345	(in 4 seconds 12345 sequence is issued to all devices)

Table 5.7. Transfer data to a coordinator (API mode AP=1)

Sending command/data	**The answer from the wireless modem**
	OK <CR><LF> (Network availability)
+++	OK <CR><LF> (Enter the command mode
ATAP 1<Enter>	OK <CR><LF> (Enable API Mode)
ATRO 1000<Enter>	OK <CR><LF> (Set delay of the packet 4 seconds)
ATCN<Enter>	OK <CR><LF> (Exit the command mode)
<Enter>12345	(in 4 seconds 12345 sequence is issued to a coordinator) OK<CR><LF> - norm ERROR<CR><LF> - error

Table 5.8. Transfer data from a coordinator to a router (API mode AP=1)

Sending command/data	**The answer from the wireless modem**
	OK <CR><LF> (Network availability)
+++	OK <CR><LF> (Enter the command mode)
ATAP 1<Enter>	OK <CR><LF> (Enable API Mode)
ATRO 1000<Enter>	OK <CR><LF> (Set delay of the packet 4 seconds)
ATCN<Enter>	OK <CR><LF> (Exit the command mode)
router1<Enter>12345	(in 4 seconds 12345 sequence is issued to a router) OK<CR><LF> -norm ERROR<CR><LF> - error

Table 5.9 Broadcast data from the coordinator (API Mode AP = 1)

Sending command/data	**The answer from the wireless modem**
	OK <CR><LF> (Network availability)
+++	OK <CR><LF> (Enter the command mode)
ATAP 1<Enter>	OK <CR><LF> (Enable API Mode)
ATRO 1000<Enter>	OK <CR><LF> (Set delay of the packet 4 seconds)
ATDN #0<Enter>	OK <CR><LF (Delete the destination node)
ATMD 6<Enter>	OK <CR><LF> (Set the delay between the frames 6 seconds)
ATCN<Enter>	OK <CR><LF> (Exit the command mode)
<Enter>12345	(OK<CR><LF> - norm (In 4 seconds. sequence of 12 345 is issued to all devices) OK<CR><LF> - rate

Record/ read from ports of coordinators of the input-output of the router (API Mode AP = 1).
In the DIO0 pin must be installed on the output (C0 = 5), the channel 1 ADC on the input (C1 = 2)

Sending command/data	**The answer from the wireless modem**
	OK <CR><LF> (Network availability)
+++	OK <CR><LF> (Enter the command mode)
ATAP 1<Enter>	OK <CR><LF> (Enable API mode)
ATRO 1000<Enter>	OK <CR><LF> (Set delay of the packet 4 seconds)
ATCN<Enter>	OK <CR><LF> (Exit from the command mode)
router1 D0<Enter>0	(In 4 seconds. The conclusion DIO0 pin in the router is being set to 0) OK <CR> <LF> - norm ERROR <CR> <LF> - error
router1 D1<Enter>	(In 4 sec. the output DIO1 in the router is being polled) OK <CR> <LF> - norm ERROR <CR> <LF> - error If OK, then router1 D1 <CR> <LF> (ADC data) <CR> <LF>

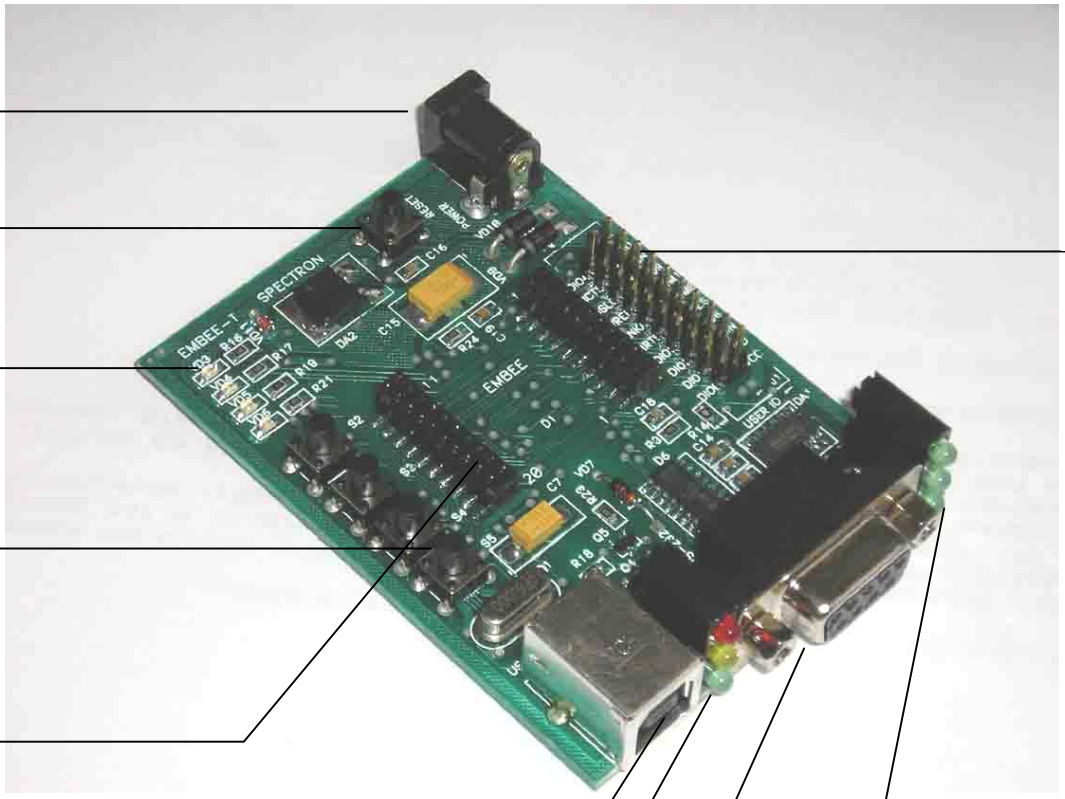
Automatic output from the router (API Mode AP = 1). API mode is also included in the coordinator.

Sending command/data	**The radio modem's answer**
	OK <CR><LF> (Network availability)
+++	OK <CR><LF> (Enter the command mode)
ATAP 1<Enter>	OK <CR><LF> (Enable API mode)
ATC0 3<Enter>	OK <CR><LF> (Set the output as a digital input DIO0)
ATC1 2<Enter>	OK <CR><LF> (Set the output DIO1 as input channel 1 ADC)
ATIR 1000<Enter>	OK <CR><LF> (Set the polling period 4 sec)
ATWR<Enter>	OK <CR><LF> (Write in the nonvolatile memory)
ATFR<Enter>	OK <CR><LF> (Restart the radiomodem)
	(Every 4 seconds in the coordinator will be issued) router1 D0 <CR> <LF> (state O) <CR> <LF> router1 D1 <CR> <LF> (ADC data) <CR> <LF>

Notes:
1. In the dynamic mode for network availability and willingness to use the data DIO8 (C8 = 1) or DIO7 (C7 = 1), setting RO = 14.
2. <Enter> = <CR> <LF> - Newline, carriage return character 0x0D, 0x0A

Apendix A. EMBEE-T Evaluation board

External device inteface



Figere A-01. EMBEE-T Evaluation board

A-01a. The test light-emitting diodes.

The test light-emitting diodes LEDs VD3-VD6 are appropriated to the ports DIO8, PWM1, DIO4, DIO5 of radio modem.
An active level is low.

A-01b. The reset button.

The reset button restarts the radio.

A-01d. The power socket.

The steady power socket 5-9V.

A-01c. The test button.

The test button S2-S5 which are corresponding to port DIO1, DIO0, DIO3, DIO2 wireless modem.
An active level is low.

A-01i. Connector for the wireless modem.

This connector is inserted EMBEE wireless modem.

A-01f.The test connector.

This connector is removed all the contacts of the radio modem. The name of contacts are described in the section "Pin assignment".

A-01g. Connector USB

The connector is for connection to PC USB port. USB pin assignment is shown in Table. A-01. Under connecting to a USB wireless modem UART connecting automatically. The wireless modem is powered-voltage USB. On the PC it is necessary to install a virtual port driver COM for the FTDI FT232BM.

Table A-01. Pin assignment USB.

Contact	Name	Description	Destination
1	VBUS	Power supply	The wireless modem power +5B
2	D-	Receiving and transmiting data	Data transmission to the wireless modem and the reception data from the wireless modem
3	D+	Receiving and transmitting data	Data transmission to the wireless modem and the reception data from the wireless modem
4	GND	General signal	General

A-01з. The UART indicator, the power supply

LEDs indicate the following signals:
- Red - the output a serial data of the radio modem nDOUT
- Yellow – the input a serial data of the radio modem nDIN
- Green - the food.

A-01i. RS-232 Connector.

A standard DB-9F connector for RS-232 PC (see Figure A-02). The appointment of using RS-232 pin is shown in Table. A-02. For the connection to RS-232 on the connector of the power it is necessary to apply a constant voltage of 5-9 V. To control the availability DIO7 is connected to the nCTS signal. The DTR signal is connected to the nSLEEP_RQpin of the wireless modem.

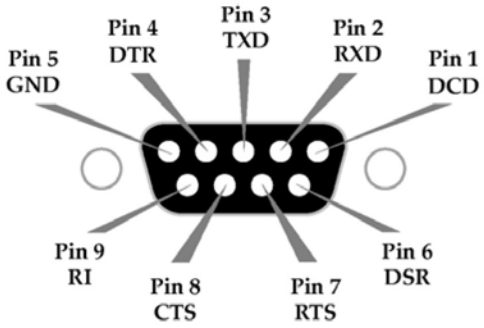


Рис. A-02. A standard DB-9F connector

Table A-02. Dedication Appointment of the accepting RS-232 pin.

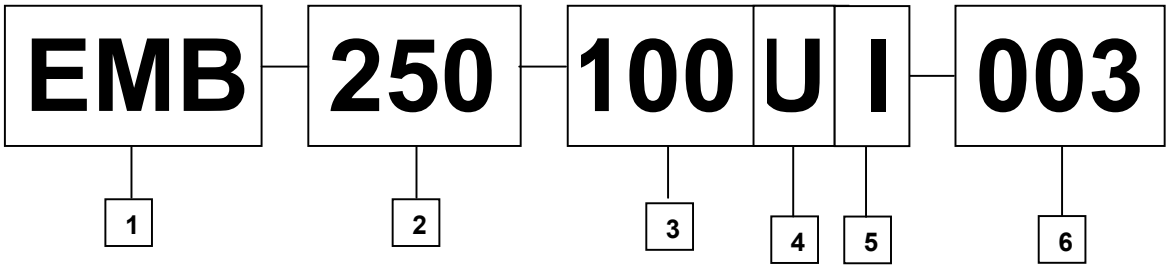
DB-9 Pin	RS-232 Name	Description	Implementation
1	—	—	—
2	RXD	Receive Data	Serial data exiting the module assembly (to host)
3	TXD	Transmit Data	Serial data entering into the module assembly (from host)
4	DTR	Data-Terminal-Ready	Can enable Power-down on the module assembly
5	GND	Ground Signal	Ground
6	—	—	—
7	$\overline{\text{RTS}}$ / CMD	Request-to-Send / Command Mode	Enables $\overline{\text{RTS}}$ flow control or Command Mode
8	$\overline{\text{CTS}}$	Clear-to-Send	Provides $\overline{\text{CTS}}$ flow control
9	—	—	—

RSSI indicator shows the strength of the received signal. The range of the received signal strength -25-91dBm. -25dBm - popping up all the LEDs,-91dBm - not on any one LED.

Appendix B: Additional information

Ordering Information

Figure. Б-01. The format of marking EMBee wireless modems.



1. Abbreviated brand EMBEE ™

2. Model of the wireless modem (EM250)

3. mW output power (100 mW)

4. Type of performance:
U - with U.FL - jack
C - with chip antenna

Five. Temperature Range:
I = Industrial (-40 +85 ° C)
C = Commercial (0 to +70 ° C)

6. Serial number of development (001-999).

Contact information

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