AT86RF211 Development Kit

User Guide

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Section 1

Introduction

1.1 Description

This kit was designed to enable you to quickly start working with the AT86RF211(TRX01) transceiver and its companion AVR® microcontroller (AT90 series).

It includes:

- An embedded **demonstration** software.

- A PC software and dongle for **RF evaluation**.

- All the tools needed to build your own stand-alone application (**development of prototypes**): batteries, LCD for debugging purposes, In System Programming, 3-bit encoder, push button, connector for external power supply adapter, etc... Software functions required to set up the transceiver and send/receive data are also provided to make it easy to write your own application software. You are welcome to reuse them when it comes to writing your own application software.

1.2 Disclaimer

- This kit must be regarded as a tool, *not* a finished product. It allows you to evaluate the performances of the AT86RF211 thanks to relevant measurement devices (oscilloscope, spectrum analyzer, etc...), design prototypes (by adding sensors or any component required by a given application) and debug software. It CANNOT be re-sold as a finished product that must be compliant with local relevant regulations.

- Since this Development Kit is intended to be used on an industrial workbench and modified by the user to build his prototypes, NO WARRANTY OF ANY KIND can apply. The user MUST read the user guide BEFORE using this kit, to know its features and use it accordingly. NO LIABILITY will be accepted by Atmel, whatsoever may arise as a result of the use of these boards.

1.3   Overview   A demo can be performed with a set of:

■ Two motherboards: AVR® microcontroller (AT90LS8535), LCD COG module, LEDS.

Figure 1-1. AVR® Motherboard

Ordering part number: AT86RF211-DK.

■ Two RF modules: plugged onto the motherboards, they operate the RF transmissions.
 Several part numbers are available, adapated to every application: long distance,
 lower cost, printed antennae and inductors.

Figure 1-2. Example of RF module
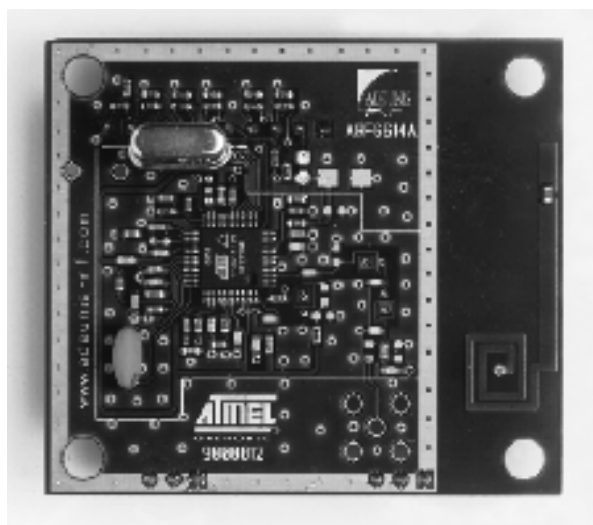
Please refer to the Bill of Material application note to choose the board that best adapts
to your needs.

Section 2
Hardware Description

All schematics and layouts are given in Appendix 1.

The RF module is ordered and delivered separately

Reset

AT86RF211 connected to:
- Dongle port
- Micro controller

3-bit encoder

LED is ON when AT86RF211 is in Rx or Tx mode

Push-button

AT86RF211 dongle port

AVR dongle port (In System Programming)

OFF-ON

External power supply (automatically disconnects the batteries)
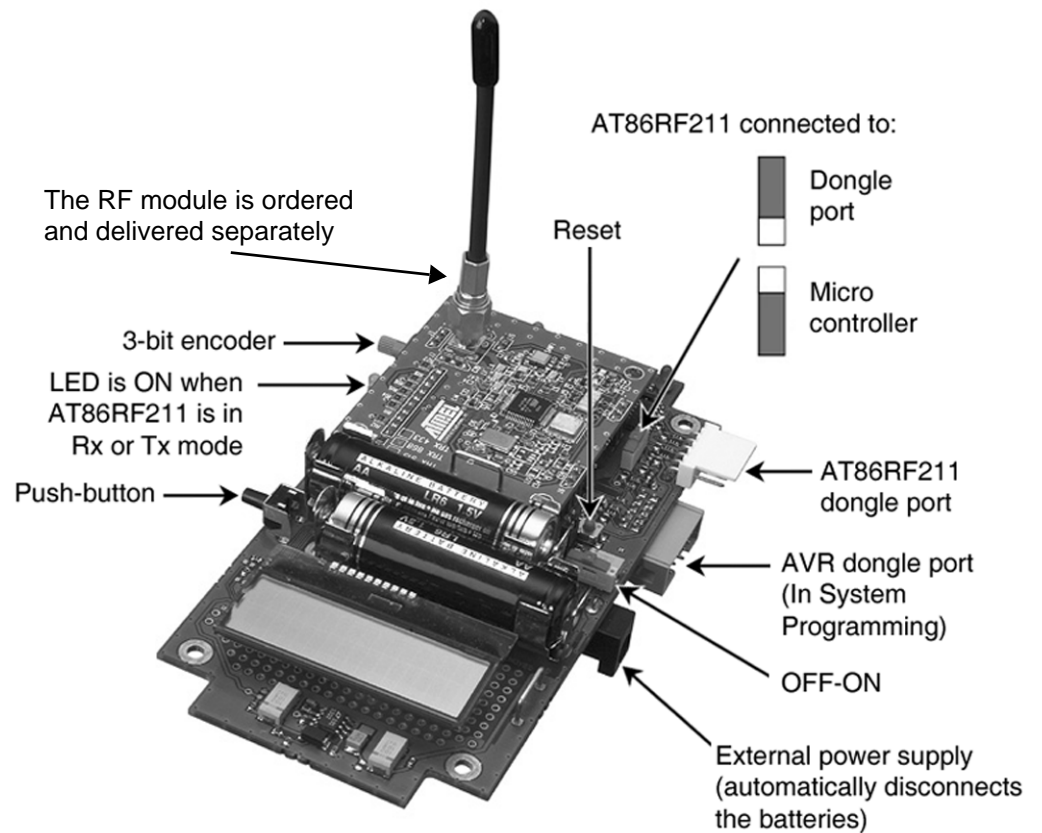
2.1 Power Supply

You can work with 1 or 2 batteries (AA or AAA) as well as an external power supply (connector J1).

Warning: The board is NOT protected against reversal, nor is a fuse mounted. Polarity MUST always be respected. NEVER apply a voltage greater than 5V to this board. If unused, BT2 battery must be replaced by a fuse F1 (typ. 0.2A). These instructions remain valid regardless of what is made with these boards.

Warning

⊙—+

5V max.
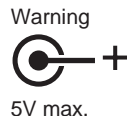
- Plugging a jack connector automatically disconnects the batteries.

Note: The AT86RF211 dongle requires a 5V power supply to work properly, as well as some AVR ISP dongles available on the market.

- NO brown-out circuit is mounted on the board, since it depends on the user's choice of power supply voltage. Mounting such a circuit is very easy since a metallized hole connected to the RESET is available close to Vcc and GND on the board (below the "ISP" inscription).

2.2 AVR® Motherboard

The main features are:

- An LCD for debugging purposes with its own step-up DC/DC converter U2 (5V output) and level translator (U3). Since a DC/DC converter is a source of noise, its input is filtered by a π stage (two low ESR tantalum capacitors and a 10Ω resistor). This resistor may have to be adapted or replaced by an inductance if higher currents are to be delivered.

Note: This 5V output is available for other circuits. If the AT86RF211 is powered through this 5V converter, output noise could decrease the performances of the transceiver, and an additional relevant filtering stage would have to be added.

- 3 LEDs for debugging purposes: DL1 (green) and DL3 (red) are connected to microcontroller ports. DL2 (yellow) is ON when the AT86RF211 is in reception or transmit mode, thanks to comparator U7 (useful for debugging Wake-Up mode protocols).

- A 2.5V Voltage Reference for the A/D converter or any other application.

- 2 buttons for Hardware Reset (S3) or external interrupt (S4).

- A 3-bit encoder (wheel) for the selection of any parameter you want.

- GR1 to GR3 to manage the DATACLK signal as an External Interrupt, a Time Input Capture or a standard Input Port depending on your needs. Demo software uses the External Interrupt input pin.

- GR4 to allow Wake-Up from AT86RF211 or External Wake-up (wired OR).

- U1 and the components around it are unused, so the user can take advantage of these footprints to place his own AOP and SMD components (also 3 footprints of SMD packages on the other side).

- A light sensor RV3.

■ A connector for In System Programming JP2. An Atmel AVR® dongle must be used, and its cable simply plugged into JP2. 5V is required by some AVR® dongles to work properly.

Several filtering stages are foreseen at critical places: radio/digital interface, connectors to the "external world". Some of them are not used on this evaluation board, but can be implemented if your application requires them without having to cut any trace. On the other hand, once the application is meeting all your specifications, it is naturally possible to cut costs by removing some of these components, such as decoupling capacitors (experience shows that it is better to do so in a second step, once everything works).

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Section 3

Using this Kit for Demonstration Purposes

3.1 Radio Parameters

The light polling demo is the software initially mounted onto any development kit delivered to customers. Its development is such that it ensures the demo is reliable without having to make any adjustments.

- Bi-phase coding is used to simplify demodulation (one transition per bit). Thus, any mounted RF module can fit.

- The Data Slicer reference level is set to external.

- The data throughput is set to 4.8 kbps, for a maximum physical baud rate of 9.6 kbps. RF211 radio modules with either a narrow IF2 filter for high selectivity or no IF2 filter can fit.

- Fixed digitally selectable frequencies are incorporated:
  - For Europe: 433.5 or 868.3 MHz
  - For the USA: 915 MHz

3.2 Protocol

The master unit sends the requested frame several times, then switches to reception mode while waiting for an answer. The slave unit scans the radio activity once every 2 seconds and responds to any valid request.

Figure 3-1. Master/Slave Data Transmission
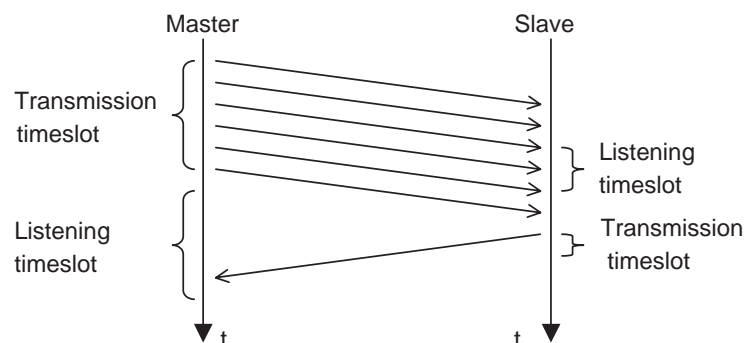
Note: This very simple protocol does not rely on any specific or optimized way to exchange data packets. On a power consumption basis for instance, the demo is not efficient. It does, however, have the advantage of being relatively robust, hence the probability of losing any messages is reduced.

3.3 Data Frames

The frames exchanged between the master and the slave have the following configuration:

Header 1 byte	Sync 1 byte	SOF 1 byte	Message size 1 byte	Message data N bytes	CRC 1 byte	EOF 1 byte
0 x 55	0 x CD	0 x A5	N		CRC8	0 x 5A

NRZ encoded   Manchester encoded

From the master to the slave, N= 1. The message is a request for information.

From the slave to the master, N = 5. The five bytes of this message include light level information (coded on 10 bits), level of RSSI, etc .

3.4 Getting Started with the Light Polling Demo

When you switch on the development kit, a splash screen welcomes you:

Light Demo V2. 06
Master – 915 MHz

Light Demo V2. 06
Slave – 915 MHz

Note: The frequency band must of course be selected in accordance with the RF module plugged into your development kit.

Press the button. The following screen appears:

Light Polling ■

The blinking black cursor indicates that you can make a selection by turning the rotary switch on the side of the development kit unit.

At this stage you can select the following menus:

Light Polling ■	PA Level ■	Frequency ■

Enter the desired menu by briefly pressing the button.

3.4.1   Light Polling   Light polling is performed continuously and the information is updated approximately every second, until the button is pressed to exit.

> **RSSI M52 S51 PA7**
> **Light 523/1023**

- The light intensity information is coded onto 10 bits, which explains why the result is given on a full scale of 1023.

- Mxx stands for the RSSI value on the master unit. Full scale is from M0 to M63.

- Sxx is also the RSSI value for the slave unit, ranging from S0 to S63.

- PAx repeats the value chosen for the Power Amplifier's amplification level (from P0 to P7).

3.4.2   Setting the PA Level   On the RF chip, eight power levels are digitally selectable thanks to three bits in the CTRL1 register. They are called TXLVL:

> **TXLVL = 2   ■**

The level can of course be adjusted by turning the rotary switch and pressing the button to confirm the choice and exit.

3.4.3   Setting the Frequency

> **Frequency band**
> **433 MHz   ■**

As before, use the rotary switch and the button to select and confirm your choice.

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Section 4

Using this Kit for (RF) Evaluation

By switching S2 to the "up" position, the AT86RF211 is disconnected from the AVR$^®$ microcontroller and connected to connector JP1 (upper right side of the board). By connecting this 6-pin connector, JP1, to a PC's printer port (via the dongle included in the kit), and using the PC software, you will be able to set up the transceiver to meet your needs (i.e. for radio evaluation purposes) and have a direct link to the transceiver's registers (i.e. for software debugging purposes).

Note: The AT86RF211 dongle requires an external 5V power supply to operate correctly (connector J1).

4.1 Software Installation

Note: This software requires a PC running Windows$^®$ 98, Me, 2000 or XP and 6 MB of memory.

1. Insert the CD-ROM in the disk drive.
2. Open the **PC Software** folder.
3. Double-click on **Setup.exe**.

The software is installed in the C:\AT86RF211 directory. It includes:

■ 'exe' and 'dll' program files

■ 'gif' and 'ini' graphic files and their locations

■ A setup file for TCL/TK programming language installation

■ A setup file to install appropriate drivers

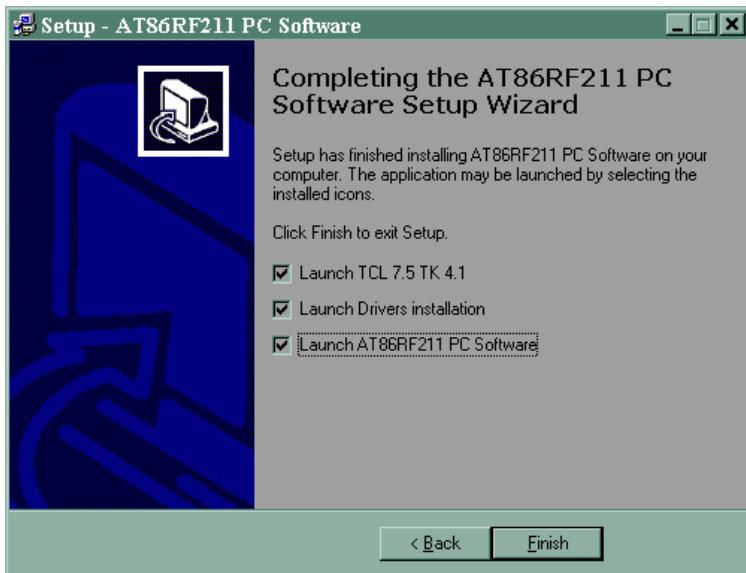■ Script and other configuration files

4. The fourth screen suggests you create a desktop icon for the program:
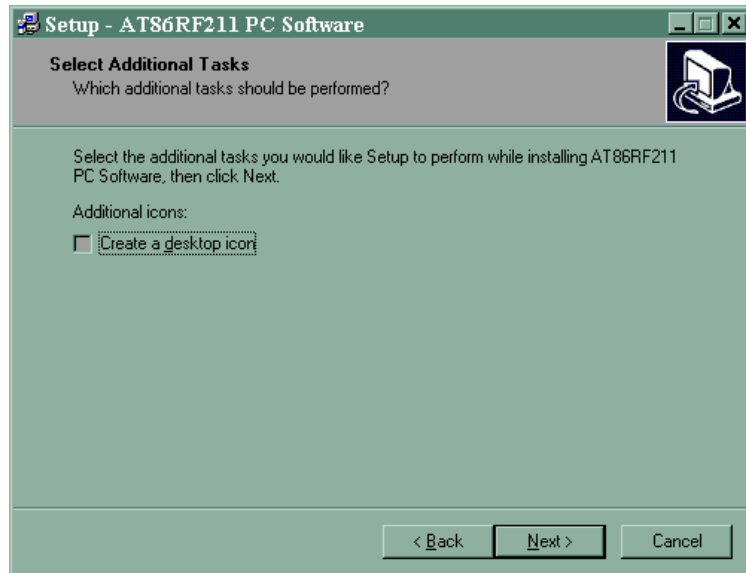
It is best to ignore this option for now. Icons can be created afterwards depending on your preferences (quicklaunch, desktop...).
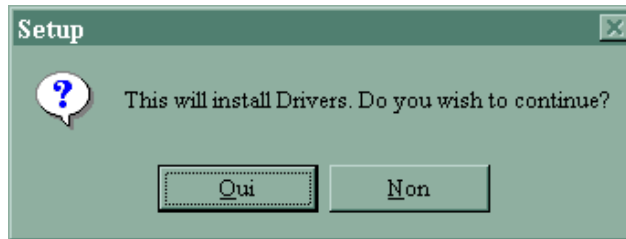
5. The program launches the installation of:

■ TCL / TK

■ Drivers

You should install these two programs before launching the software itself.

6. Install the drivers and launch the software.

Note: On Windows 98, the following screens appear in french:

This screen asks you to insert the 'Jungo Installation Disc'. Simply click *OK*.

This screen explains that the file 'windrvr6.sys' on the Jungo Installation Disc cannot be found and that files should be copied from C:\AT86RF211\Drivers. Ignore these messages and continue the installation by clicking on *OK*.

7. Install TCL 7.5 and TK 4.1.
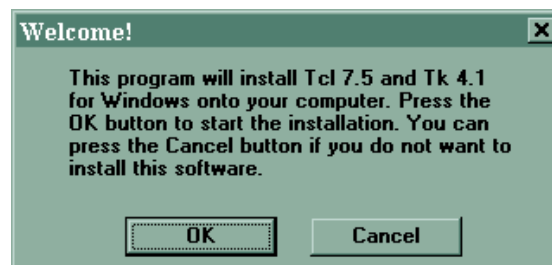
The PC software is now ready to run and the desktop icon can now be created.

| 4.2	Software Description	*Note:* To close the program properly, ALWAYS use the **Exit** button (not the "X" at the upper right hand corner of the window).

This evaluation software comprises two main screens:

■ **SETUP screen:** you can "manually" describe the AT86RF211 configuration wanted or load a pre-registered set-up by pressing LOAD. The main menu is called **Setup_AT86RF211(TRX01)**. You may also enter the PRE-SETUP menu for less frequently performed actions.

■ **DEMO screen:** open the DEMO screen by clicking on **EXECUTE** from the SETUP window. The configuration is sent to the AT96RF211, and a link is established with the transceiver. It also gives you access to the contents of the registers.

The main menu is called the **demo_ AT86RF211(TRX01)** menu, where you are able to:

    – RESET (AT86RF211 hardware reset)

    – DEBUG (direct link with all AT86RF211 registers)

    – View registers' contents (VIEW CTRL & STAT REG, VIEW FREQ…)

    – Etc...

4.2.1 SETUP (Programming Menu)

1. When the software is run, the SETUP menu appears. It provides quick access to the configuration of parameters that are most frequently changed. Other parameters are changed in the PRE-SETUP. Click on PRE-SETUP at the bottom of the SETUP window to change menu windows.
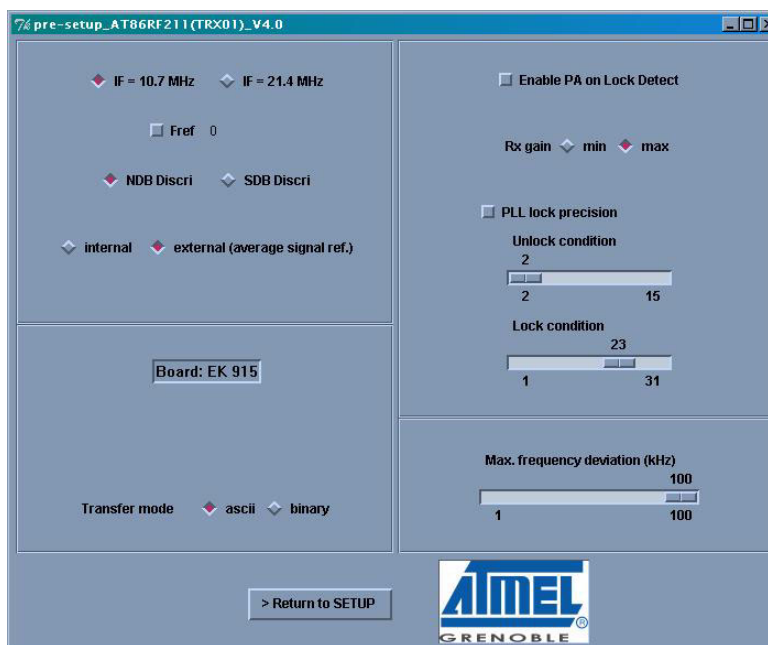

You can modify the default or loaded configuration according to your application:

■ **IF Frequency**: 10.7 MHz for cost reduction (low cost filter, requiring a 10.245 MHz crystal), or 21.4 MHz for better image rejection (more expensive filter, requiring a 20.945 MHz crystal).

Note: The IF filter and the crystal have to be chosen accordingly.

- **FM BW** (FM bandwidth): must be set in accordance with the application note "Understanding the Demodulation and Data Slicing Features", concerning the relationship between data rate, frequency deviation and demodulator capabilities.

- **Data Slicer Threshold**: the output of the discriminator can be compared to:
    - An internal threshold ("internal mode"): "absolute" slicing is possible (no need to have a DC free message) but the threshold must be properly measured and stored into the relevant register.
    - Its own average value ("external mode"): the baseband signal must be DC free.

- **Enable PA on Lock Detect**: transmission is forbidden until the PLL is locked.

- **PLL Lock Precision**: definition of lock and unlock "diagnosis" (please refer to the datasheet for more details about this point, default values are valid for many applications).

- **Maximum Frequency Deviation (kHz)**: indicates the maximum frequency deviation that can be chosen in the SETUP menu.

2. Once pre-setup is completed, click on **Return to SETUP** for configuration of other parameters. You are now able to specify the main parameters of the AT86RF211.

- Operating mode:
    - **PDN** = Power Down
    - **RX** = Receive mode
    - **TX** = Transmit mode
    - **PDN/PA** = Transmit mode but the output is switched OFF (application: can be instantaneously turned to TX mode for applications where a quick answer is critical).

- Automatic computing of frequencies (**TX mode**):
    - Enter your frequency channel, the deviation and then click on **COMPUTE**. The software will calculate and display the two closest frequencies (F0 for logical "0" and F1 for logical "1") that the AT86RF211 is able to synthesize. "eps [Hz]" gives you the errors between expected and actual synthesized frequencies.
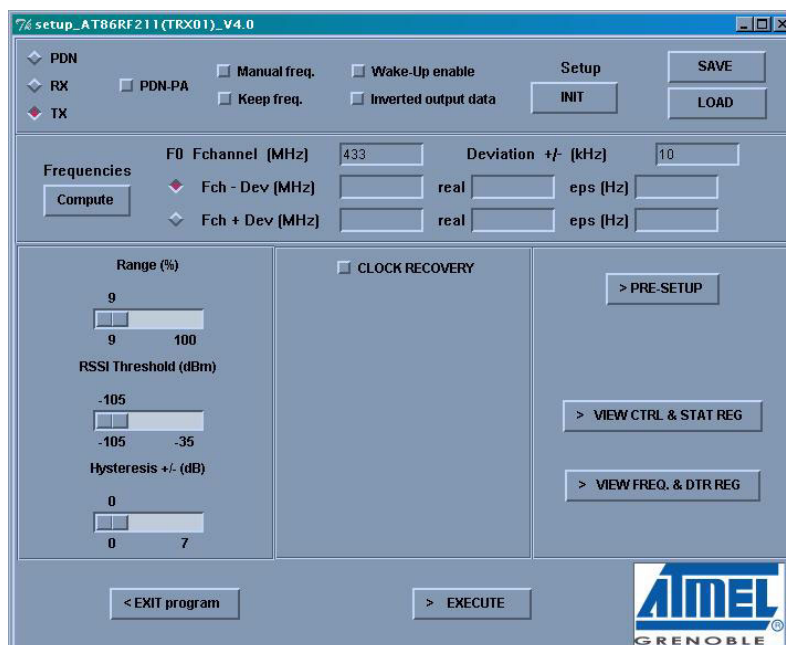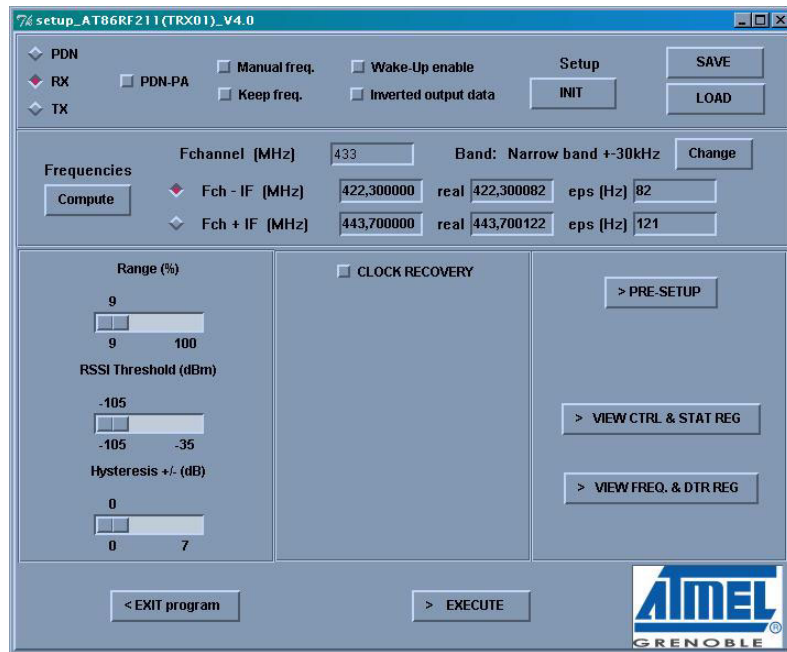
– Each frequency is coded with 32 bits. (Fch - Dev) corresponds to logical "0" and (Fch + Dev) corresponds to "1". **These 2 x 32-bit will be written by the software in the relevant registers.**

Warning: There is NO simple relationship between F (in MHz) and these 2 x 32-bit, please always use this procedure to find out the bits that must be written in registers (do NOT try to modify the bits directly!).

– The maximum frequency deviation authorized in the PRE-SETUP window must not be exceeded. The IF value (as defined in the PRE-SETUP menu) is naturally taken into account.

■ Automatic computing of frequencies (**RX mode**):

– Enter your frequency and choose the band corresponding to your receiver, then click on **COMPUTE**. The software will calculate and display the two frequencies F2 and F3 (corresponding to the Upper Side or Lower Side Band) the AT86RF211 is able to synthesize. "eps [Hz]" gives you the difference between desired and synthesized frequencies.

    – Each frequency is coded with 32 bits. **These 2 x 32-bit will be written by the software in relevant registers.**

Warning: There is NO simple relationship between F (in MHz) and these 2 x 32-bit, please always use this procedure to find out the bits that must be written in AT86RF211 registers (do NOT try to modify the bits directly!).

Note: By default, F0 and F1 will be chosen for emission and F2 (= Fchannel-IF) for reception. But keep in mind that this situation can be modified by changing TXFS and RXFS in register CTRL1 (advanced function).

■ **Receiver band choice**:

This parameter has to be selected carefully in accordance with the application bandwidth.

No Band :   The calculation of the LO register is made without optimization in relation to the receiver bandwidth.Normally not to be used.

Narrow Band :   The calculation of the LO register is made with optimization in relation to the receiver bandwidth. To be used if a 455 kHz ceramic filter or a narrow band 10.7 MHz ceramic filter is used => Band Width of the receiver less than 60 kHz. The accuracy of the synthesizer is **typ. 200 Hz.**

Medium Band :   The calculation of the LO register is made with optimization in relation to the receiver bandwidth. To be used when no 455 kHz ceramic filter is mounted and the bandwidth of the 10.7 MHz ceramic filter is $\leq$280 kHz => bandwidth less than 300 kHz. The accuracy of the synthesizer is **typ. 400 Hz**.

Wide Band :   The calculation of the LO register is made with optimization in relation to the receiver bandwidth. To be used when no 455 kHz ceramic filter is mounted and the bandwidth of the 10.7 MHz ceramic filter is

>280 kHz => bandwidth less than 600 kHz. The accuracy of the synthesizer is **typ. 1 kHz** with a maximum of approximately 3 kHz.

- Other possibilities for frequency management:
    - The 4 frequency registers can be computed one after the other: click on **Manual freq.**, fill in the frequencies and click on **COMPUTE**.
    - **Keep freq** option: "freezes" frequencies: they will no longer be changed inside the AT86RF211 when going from the SETUP to DEMO.

- **Inverted Output Data** option changes the polarity of the output data.

- **RX general parameters**:
    - **Range (%)**: sets the level of output power, from 100% to 9% of maximum power set by R_{POWER}.
    - **RSSI threshold (dBm)**: data reception output is inhibited if RSSI is lower than this level.
    - **Hysteresis ± (dB)**: hysteresis associated to the previous level.
    - When **Clock Recovery** is enabled, the data rate and data rate tolerance appear and must be set to the desired value (rounded to the nearest value the transceiver is able to generate).

- **View of register values** (corresponding to the chosen configuration):
    - **View CTRL & STATUS REG**: image of CTRL1, CTRL2 and STAT registers.
    - **View FREQ & DTR REG**: image of the 4 frequencies and DTR registers.

3. To save a given configuration, click on **SAVE** and enter a name xxxx.cfg.
4. To load a given configuration click on **LOAD** and enter the name xxxx.cfg of a previously saved configuration.
5. Click on **INIT** to go back to the default RESET configuration of AT86RF211.

4.2.2   DEMO (Action Menu) 1. When you click on **EXECUTE**, the defined configuration is sent into AT86RF211 (if not already done, the frequency codes are automatically computed). The link with AT86RF211 is established and maintained, and the state of AT86RF211 is **continuously** displayed:

- Battery level, state of the PLL (locked/unlocked) and RSSI level in Rx mode.
- Battery level and state of the PLL (locked/unlocked) in Tx mode.

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> ***Note:*** "PLL LOCKED" MUST be green (if not, the link with AT86RF211 is NOT properly established).

2. It is possible to change parameters in real time. Changing parameters in this demonstration will change the AT86RF211 configuration and also the parameters in the SETUP menu.
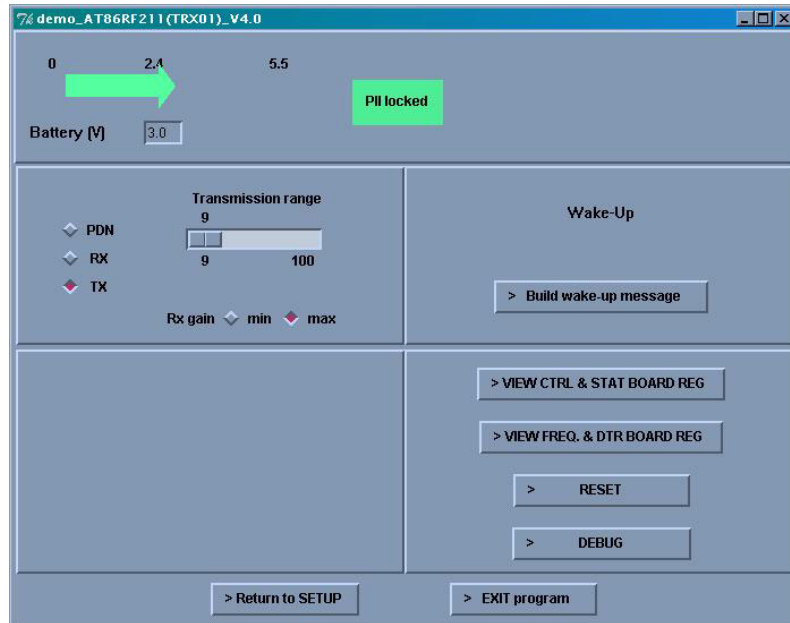
3. You have the possibility of modifying, in real time, the following features of the AT86RF211:
    – State: **PDN** = Power Down, **RX** = Receive mode, **TX** = Transmit mode
    – Power output amplitude, from 100% to 9% of maximum power set by R_{POWER}.
    – **Rx gain** = LNA gain
4. You have also the possibility of seeing the state of registers:
    – **View CTRL & STATUS BOARD REG**: image of CTRL1, CTRL2 and STAT register
    – **View FREQ & DTR BOARD REG**: image of the 4 frequencies and DTR registers
5. Click on **RESET** to set AT86RF211 in the Reset state (refer to the datasheet for values).

4.2.3   DEBUG Mode   This mode allows you to have immediate access to any registers: bit-by-bit write/read of any register (also useful for software debugging).
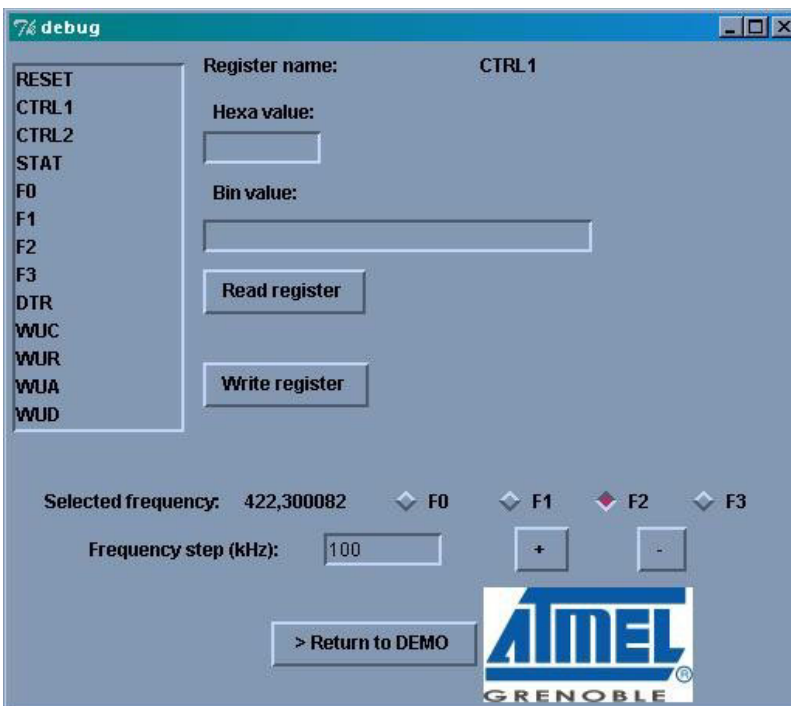
To do so:

1. Choose a register in the list on the left side of the window.
2. Click on **Read register**. The value is displayed.
3. Modify the **Hexa value** or the value of a bit.
4. Click on **Write register**. The register is modified. You can verify the modification by reading the register again.

Warning: You MUST stay in this window during all debug work. If you go back to the DEMO window, the software will periodically write and read registers to update displayed data and register values may be modified.

The Frequency can be modified step by step:

1. Click on the frequency you want.
2. Enter the step (i.e. 100 kHz).
3. The shift is performed when you click on the **"+"** and **"-"** buttons.

Warning: Do NOT try to modify frequencies by changing bits into registers. There is no simple relationship between F (in MHz) and the corresponding 32 bits.

4.3 Example: Measurement of Output Power and Spectral Purity

Set-up the chip as a Transmitter in order to measure its parameters: peak power, spectrum purity (the input attenuator of spectrum analyzer should be > 40 dB).
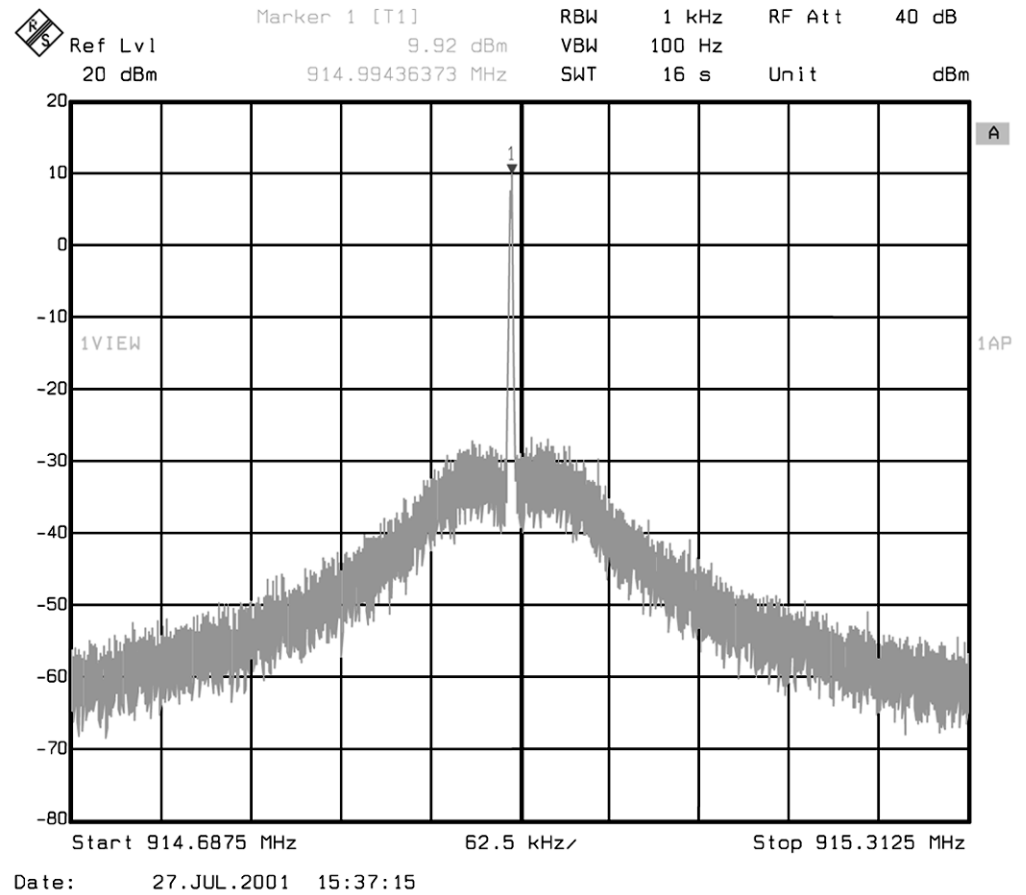
4.4   Example: Measurement of Sensitivity

Set-up the chip as a Receiver. Tune an RF generator (i.e. 868 MHz, FM, deviation = 4 kHz, square modulation 50% 1kHz, -30 dBm). With an oscilloscope:

■ Look at 10.7 (or 21.4) MHz IF, 455 kHz IF

■ Look at FM discriminator output and data slicer output (= DATAMSG, see location on the following photo).

You can get an initial idea of the sensitivity by reducing the RF level until the DATAMSG disappears (an actual measurement would measure BER). Typical sensitivity of this board is around -100 dBm in previous measurement conditions (for a BER = 0.01).

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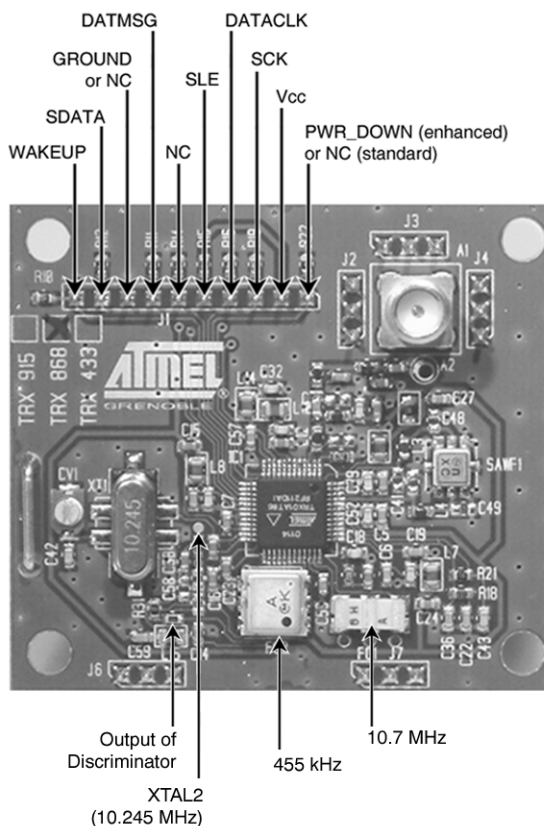
Section 5

Using this Kit to Develop Prototypes

As you can see, space is available on the motherboard for your application. You can solder the components you need on this prototyping area and connect them to the AVR® (either to an unused port or in place of a demo sensor). A via with the printed port name is available for all microcontroller's I/O ports and some other components. Names of the different vias are given on the schematics. Note that all of them are on the AVR® side except PD1 (named d1).

The AVR® may be disconnected easily (PLCC socket), if not the user only needs access to the transceiver, or uses another AVR® part number.

Once your hardware platform is designed, you can use the basic Software Functions to write your application in C-language, and download it into the AVR® thanks to In System Programming possibilities. An Atmel AVR® dongle is required (i.e. AT AVR ISP, or STK 200, 300 or 500 AVR Starter Kit). Note that some dongles also require 5V to work properly.
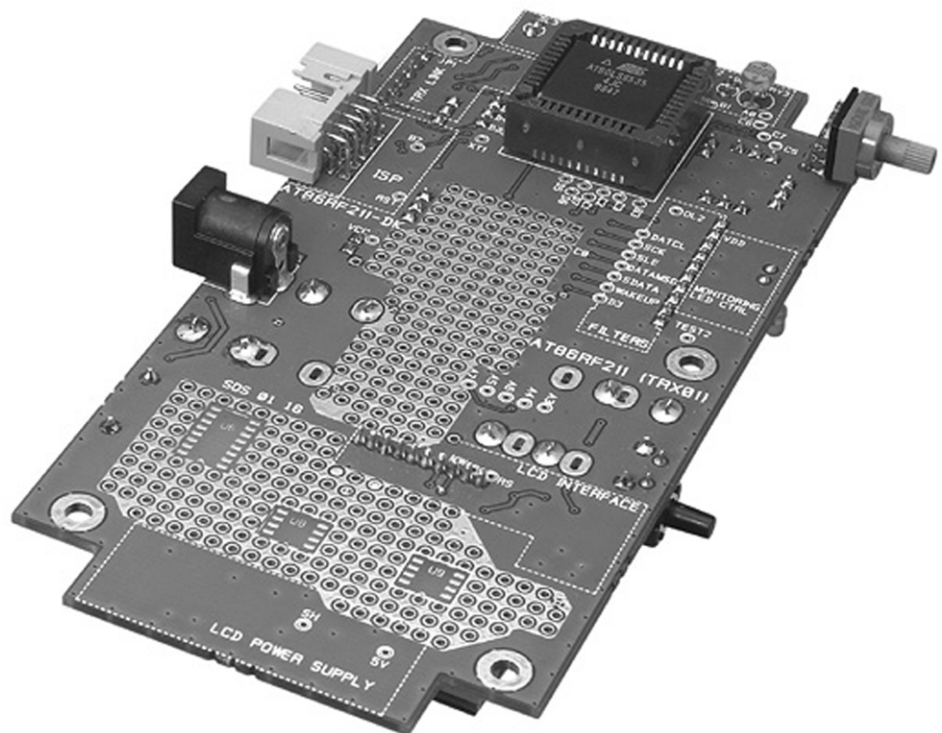
Remark: An easy way to **find out the values of registers corresponding to a desired configuration** is to use the dongle PC software. Define the configuration you want by clicking on the relevant options, then click on **EXECUTE** and read the corresponding values of registers (VIEW CRTL & STAT REG, etc...). Verify that the MVCC bit of CTRL1 is set-up as you require, since the software alternatively (and automatically) switches from reading RSSI to VBAT [MVCC = 0 for RSSI and = 1 for VBAT].

Notes: **1.** The choice of microcontroller (AT90LS8535) was made to offer the user a broad range of features (8k Flash, UART, etc...), and therefore to be suitable for almost any kind of application. However, software functions were always written using the smallest resources possible, in order to make it possible to download the software into a smaller MCU for the final application (cost reduction).

2. The PLCC package was chosen to allow emulation or use of another AVR. Part Number. Naturally, you can use Atmel relevant tools (simulator, Emulator…) for debugging purposes. Please see www.atmel.com to find a list of available tools.

Section 6

Schematics, Layout and Additional Software Tools

6.1 **Schematics and Layout**

Please refer to Appendix 1 "Schematics and Layouts" in the User Guide.

6.2 **Additional Software Tools for Sleep Mode Implementation**

Please refer to Appendix 2 "Sleep Mode Implementation" in the User Guide.

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