nRF24L01+ TEST SETUP

INTRODUCTION

This document describes the different tests that can be done with the nRF24L01+ EVKIT. The tests can be divided into three categories: RF performance tests, Range test and protocol test.
It is required to read the documents describing the hardware and the software before these tests are performed.

RF PERFORMANCE TEST

This chapter describes a basic RF performance test; measuring the out put power and how to measure the current consumption of the nRF24L01+ in different modes.

Measuring the output power

To measure the output power, a PC running the nRF24L01+EC software, a nRF24L01+ EVSYSTEM with the nRF24L01+ REFMOD with SMA connector and a spectrum analyzer are needed.

Connect the equipment as shown in Figure 1.

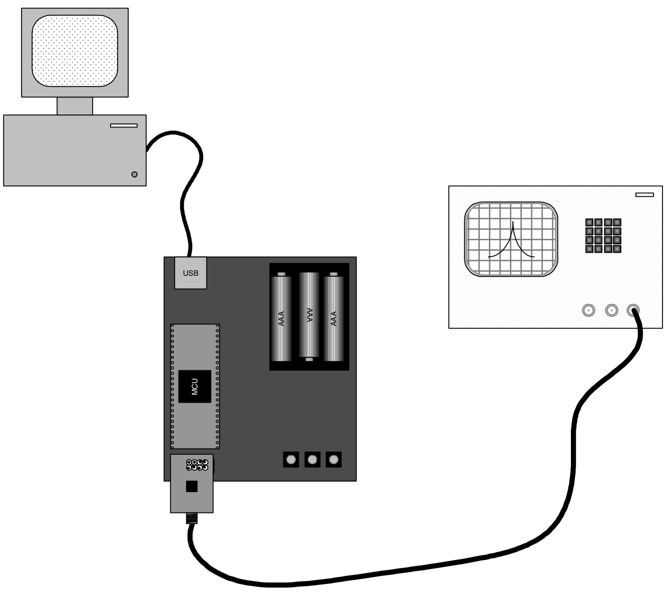

Figure 1: Test setup for output power measurement

Enter the “Test Mode” window in the nRF24L01+EC software and apply the following settings:

- Set the RF frequency to the frequency to be measured.
- Set 0dBm RF Power
- Check “Power Up”
- Check “CE”
- Check “Tx Mode”
- Check “Carrier”

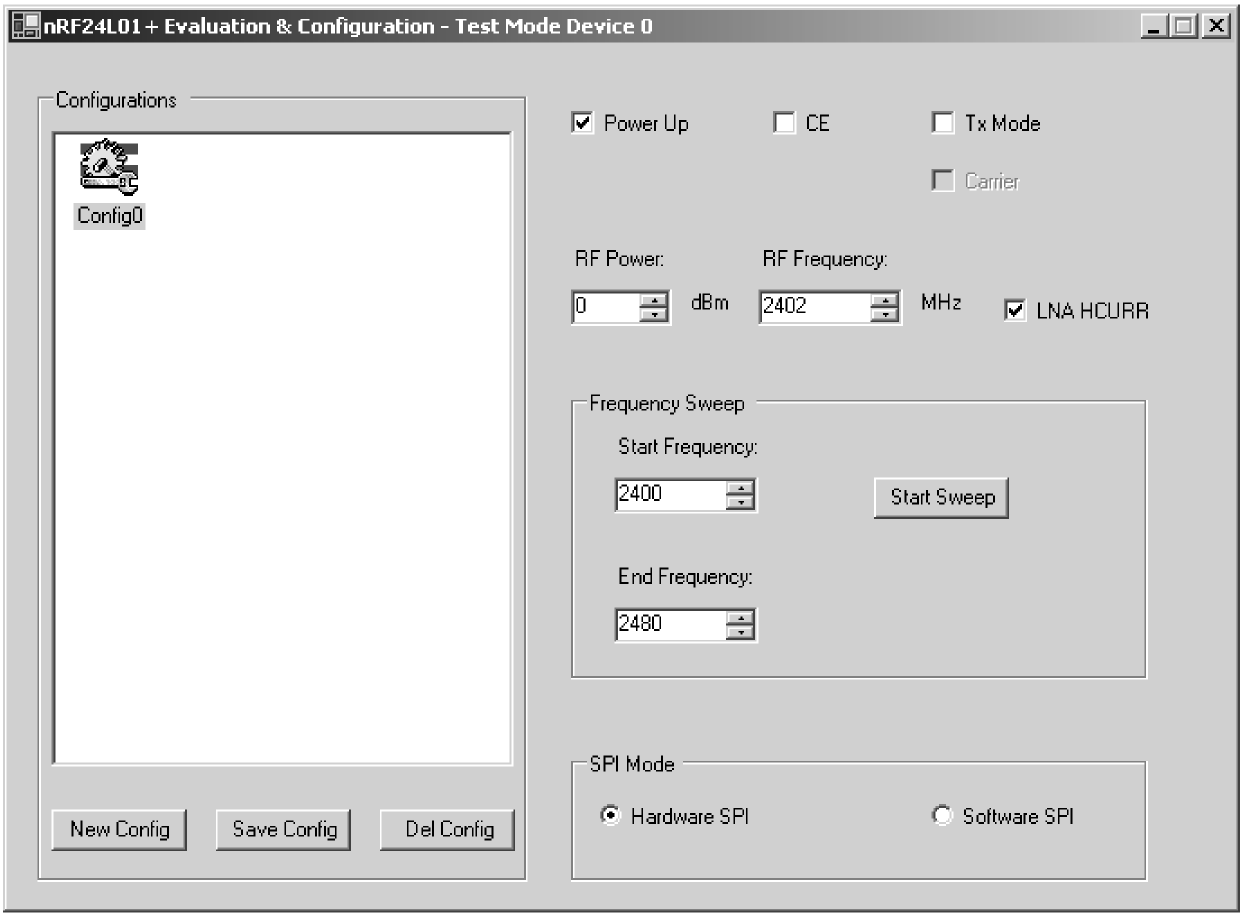

Figure 2: Test mode

A carrier should now be visible on the spectrum analyzer.
Please note that the carrier seen in this mode is not a clean carrier. During this test, the TX PLL is locked (during normal operation it operates in open loop) and the carrier is generated by re-transmitting a packet. The packet contains only “1” in address and payload, but the preamble contains 8 bits of alternating “1” and “0.” This will cause some modulation of the carrier. This carrier is only intended to be used during measurement of output power.

Measuring the current consumption

By replacing the jumper “J101” on the nRF24L01+ EVSYSTEM Basic Feature Board with an ampere meter, it is possible to measure the current drawn by the nRF24L01+ REFMOD in any operating mode. Select operating mode in the nRF24L01+EC Test mode window.

RANGE TEST

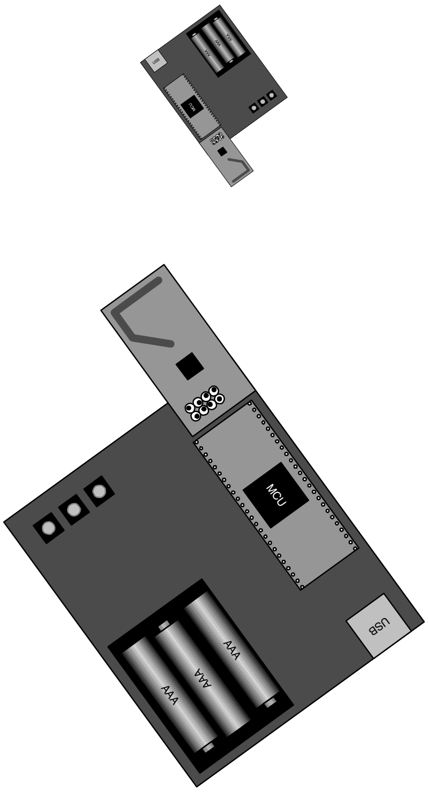

Figure 3: Test setup for range test

This chapter describes a typical range test with the nRF24L01+-EVKIT. To perform this test, two boards have to be setup, one for the RX device (USB 0) and one for the TX device (USB 1), but **not** in frequency agility mode. If you install batteries in both modules, you are able to disconnect the modules from the PC, after configuration, and perform a mobile range test with them.

Follow these steps to initialize the boards for Range Test:

RX DEVICE SETUP

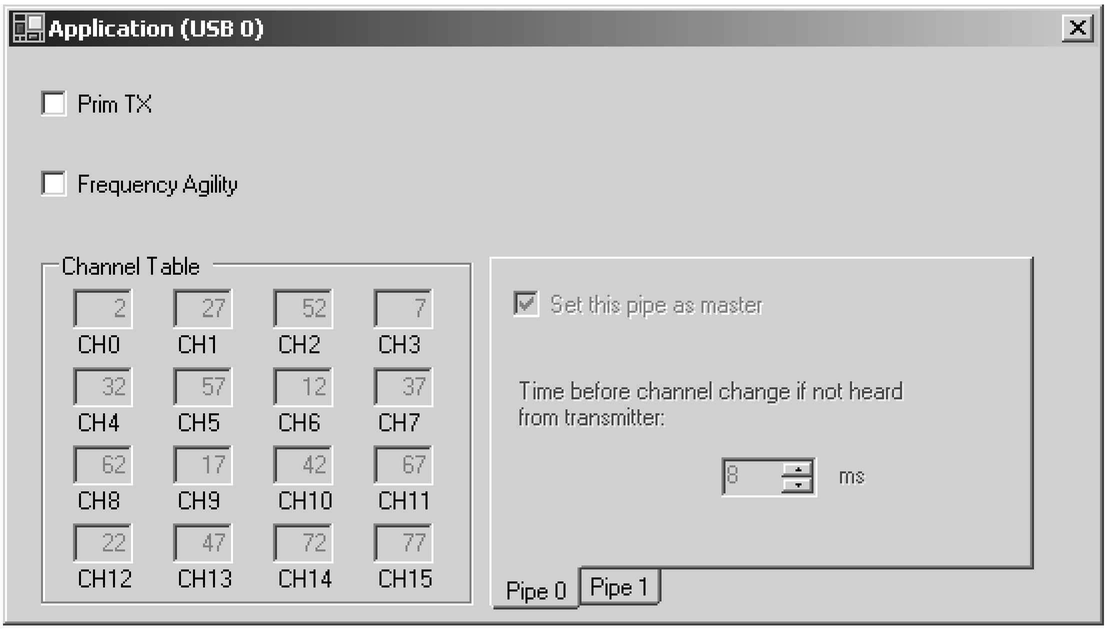

Figure 4: “Application”, RX device

Deselect “Prim TX“ and “Frequency Agility” as shown in Figure 4. These selections will make this a RX device and disable frequency agility mode. Close the Application window to apply the settings. Open the “RF Parameters” window, Figure 5, and make a RF Frequency selection, for instance “2440”.

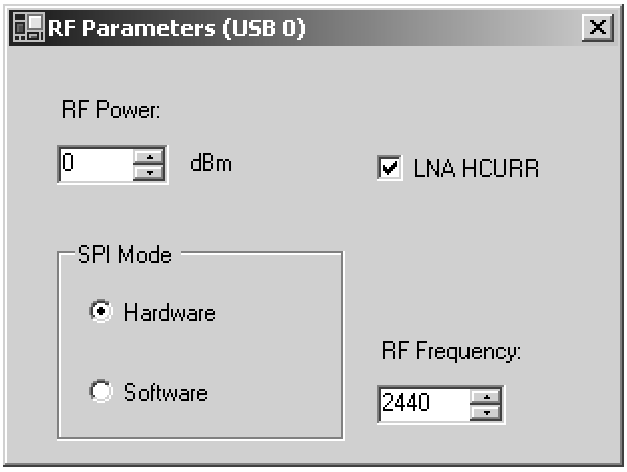

Figure 5: “RF Parameters”, RX device

Now, make sure that “Pipe 0” is enabled and that the auto acknowledgement for this pipe is enabled, like Figure 6.

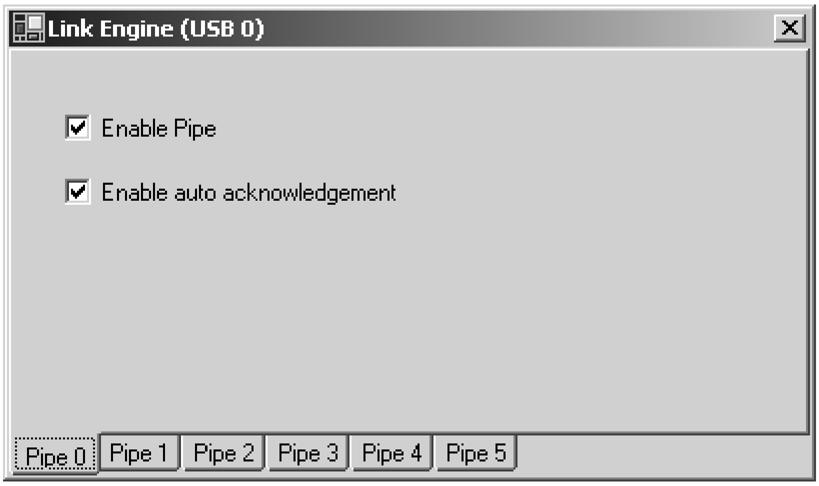

Figure 6: “Link Engine”, RX device

In the “Shockburst” window, Figure 7, make sure that the “Address”, “CRC” and the “Payload Length” is the same as for the TX device. By using the default values after reset, i.e. unplug and the plug inn the USB cable, the default settings are the same for both the RX and the TX device.

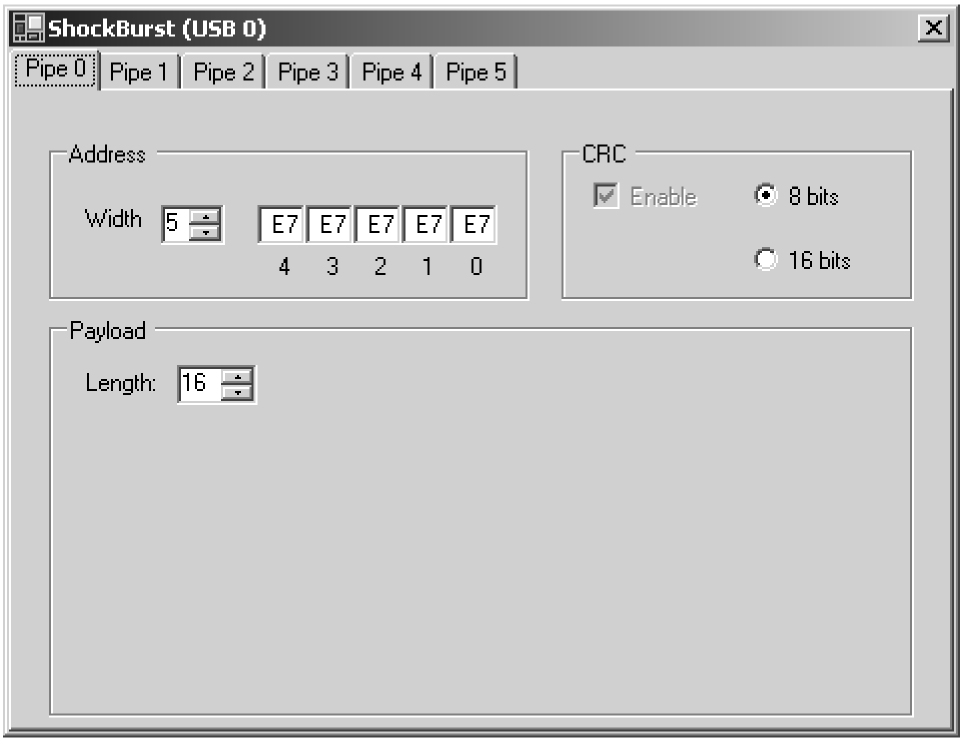

Figure 7: “Shockburst”, RX device

Finally, press the "Start Communication Mode" button, Figure 8, and the RX device is ready to receive data from the TX device.

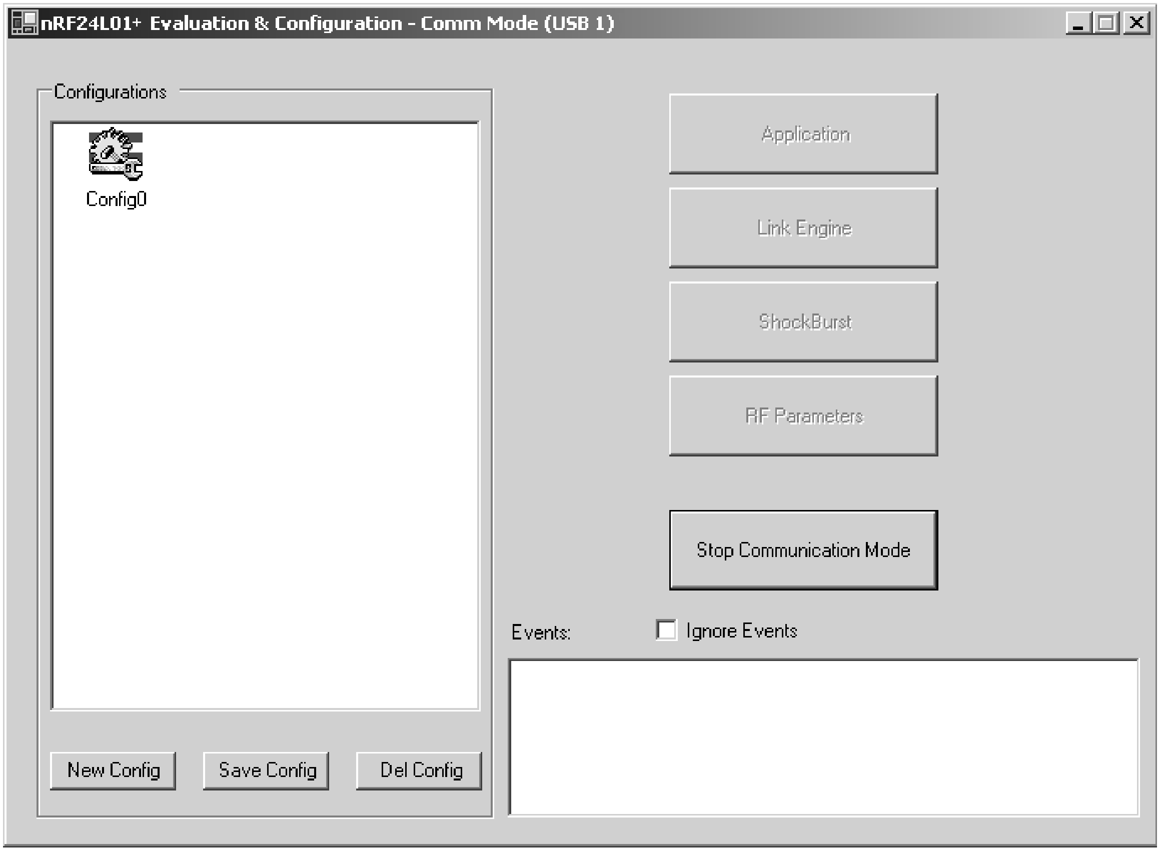

Figure 8: RX device started

TX DEVICE SETUP

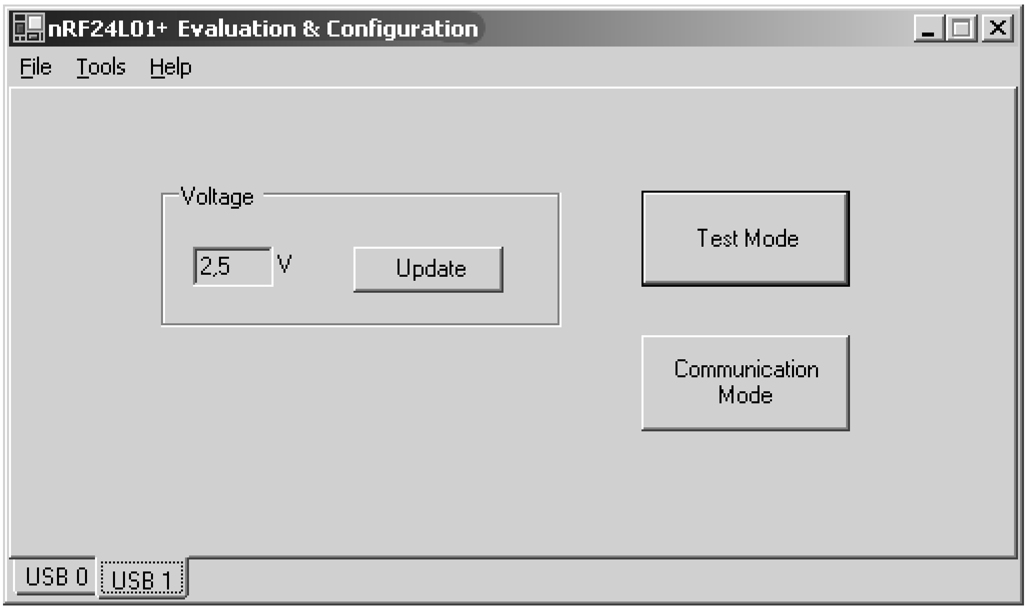

Figure 9: "USB 1" selection

Select the "USB 1" device, and enter the "Communication Mode".
In the "Application" window, Figure 10, select the "Prim TX" and make a selection for the "Timer", 10ms will be just fine. The TX will then send a packet every 10ms. Ensure that "Frequency Agility" is turned off.

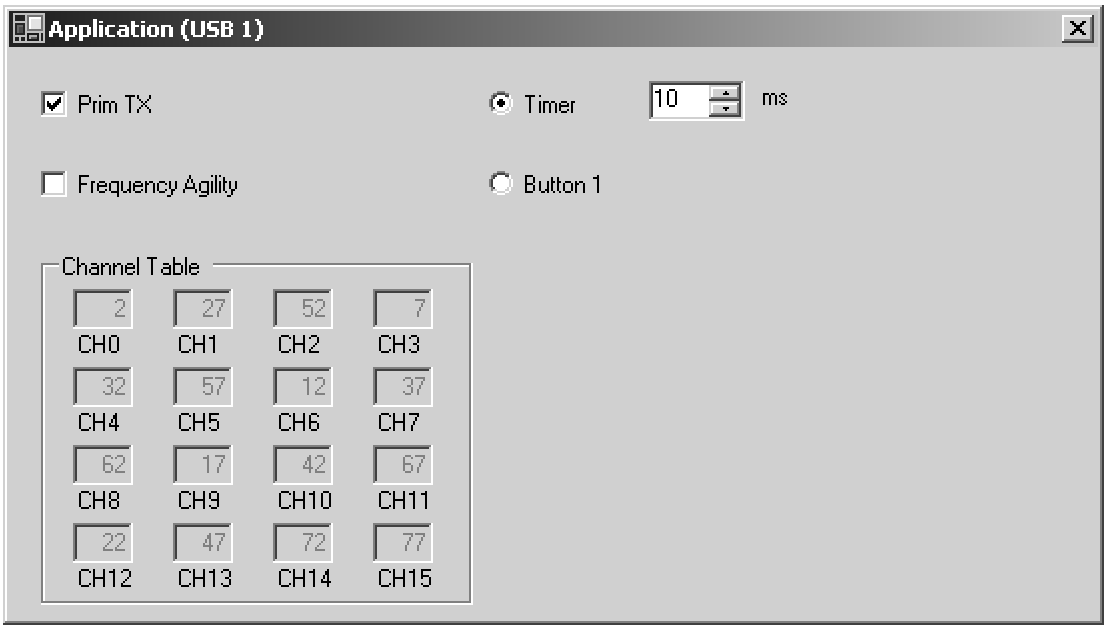

Figure 10: "Application", TX device

In the “RF Parameters” window, Figure 11, select the same “RF Frequency” as was selected for the RX device, in this example, “2440”.

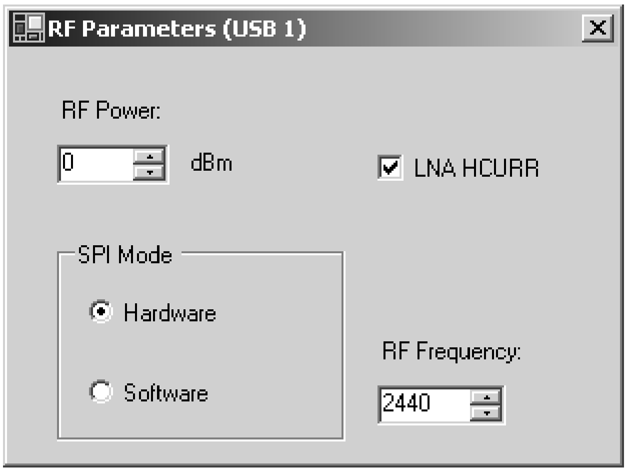

Figure 11: “RF Parameters”, TX device

Make sure that the “Enable auto acknowledgment” is selected, Figure 12. “Auto retransmit count” and “Auto retransmit delay” can be unmodified.

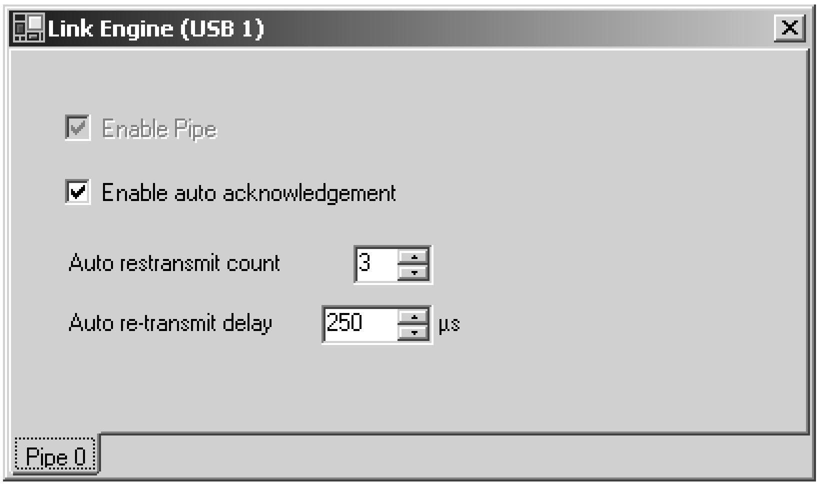

Figure 12: “Link Engine”, TX device

In the “Shockburst” window, make sure that address width, address, CRC and payload length is the same as for the RX device.

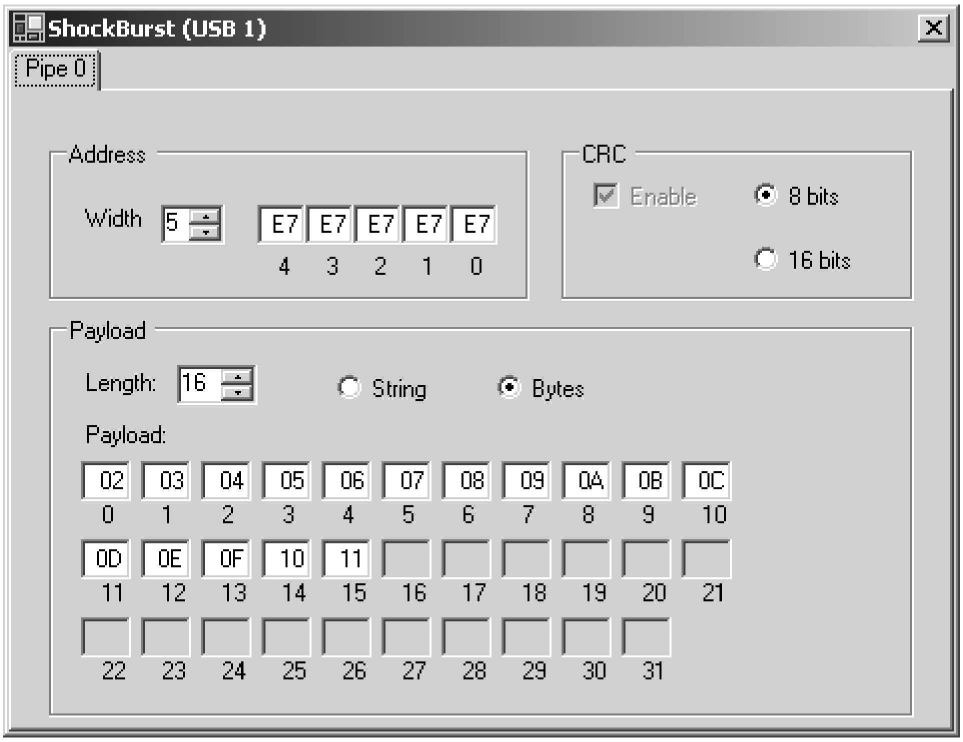

Figure 13: “Shockburst”, TX device

Press the "Start Communication Mode" for "USB 1", and the TX device will start, Figure 14.

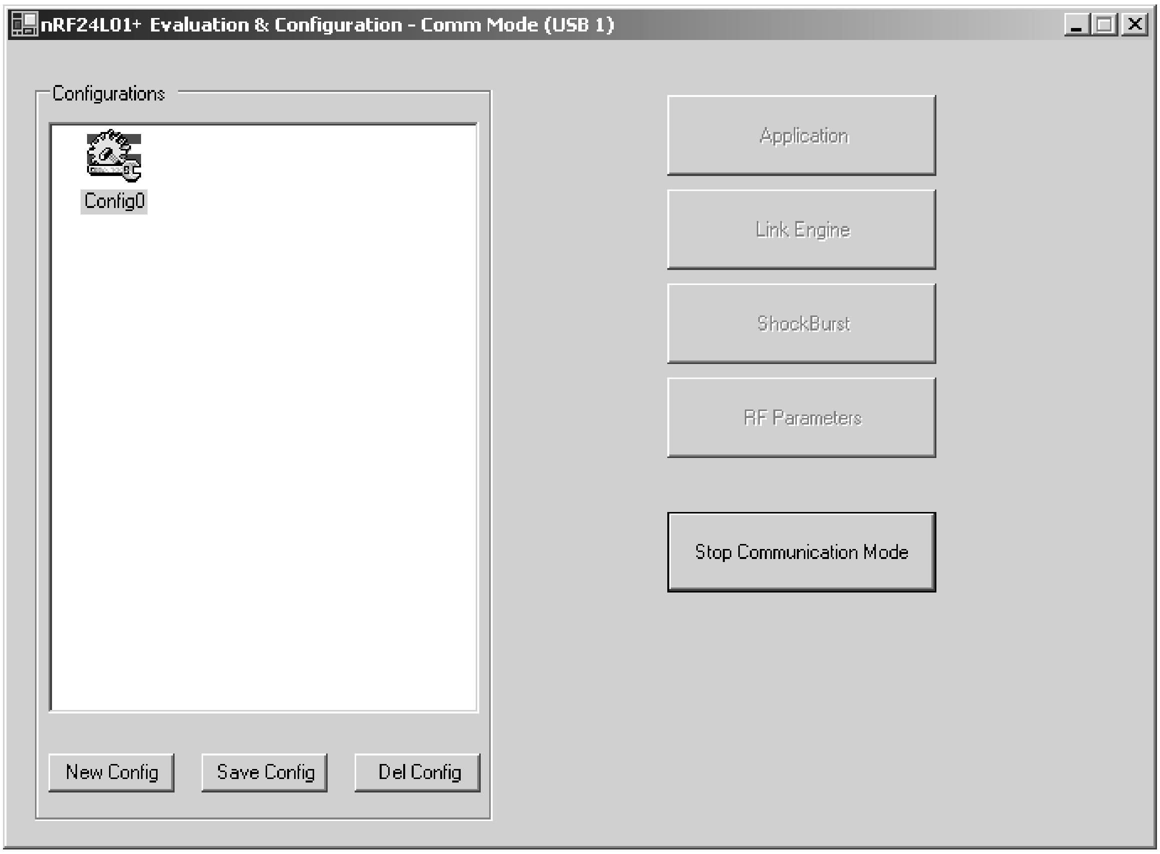

Figure 14: TX device started

On the TX device, "LED 2" will blink each time one packet is tried to be transmitted, and the "LED 1" will blink each time the packet is successfully transmitted. LED 3 will blink every time Maximum Retries has occurred.

On the RX device, the "LED 2" will blink for each received packet.

Now, if batteries are mounted in the TX device module, you can turn on the battery switch, and unplug the USB cable. This module is now mobile, so the range can be measured by moving it around.

- On the RX device, when LED 2 stops blinking, the range limit has been reached.
- On the TX device, when LED 1 stops blinking, and only LED 2 and LED 3 blinks, the range limit has been reached.

Expected range with the nRF24L01+ REFMOD with PCB antenna is more than 10 meters.

PROTOCOL TEST

Figure 15: Test setup for protocol test

This chapter describes a protocol test using “Frequency Agility Protocol” (FAP), and during this chapter an example setup will be specified. Parameters in FAP mode are herein adjustable for the user, but this chapter will describe one typical setup.

This test requires two modules, but can additionally be expanded with three, that is: running FAP on one pipe, and adding one pipe for a follow mode device. Follow mode in this system means that for this pipe, the RX device is not expecting data within a specified timeslot, as for the FAP pipe, so the RX device will not switch channel if no data has been received on this pipe.

First we will setup the RX device, and start it up, ready to receive data. The RX device is setup for FAP on pipe 0, and follow mode on pipe 1.

RX DEVICE SETUP FOR FREQUENCY AGILITY MODE

Using “USB 0” as the RX device, enter the “Communication Mode” for this device, and click the “Application” button. The settings for this device should be like those on Figure 16.

These settings initialize a RX device running frequency agility on pipe 0, and set a frequency agility timeout of 8ms. This means that the RX will change channel if no data is received on this pipe within 8ms from the last reception. It also shows that both pipe 0 and pipe 1 is enabled for this device. Keep in mind that the frequency agility timeout value for the RX device must play along with the timer value for the TX device. This will be commented in the TX device setup part of this document.

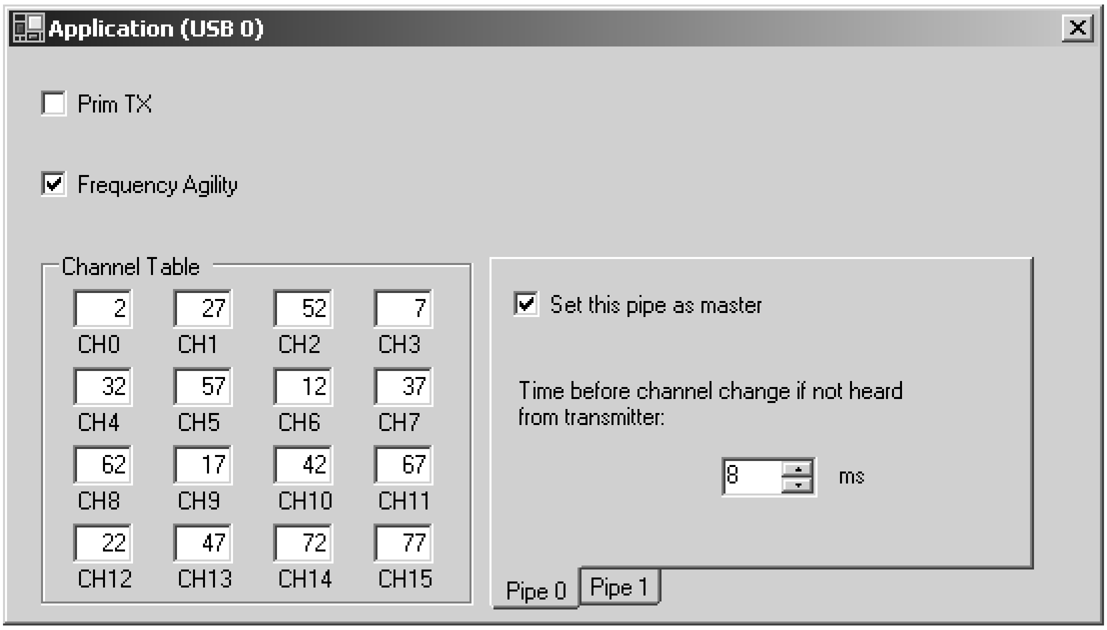

Figure 16: "Application", RX device, FAP mode

Moving to the “Link Engine”, Figure 17, the “Enable Pipe” must be selected for both pipe 0 and pipe 1. Since we are running in FAP mode on one pipe, “Enable auto acknowledgment“ is forced selected.

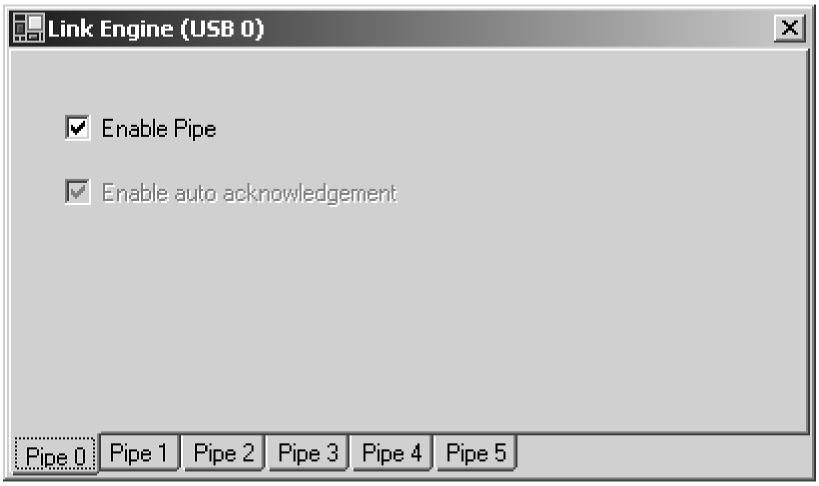

Figure 17: "Link Engine", RX device FAP mode

Now, the “Shockburst” settings are to be initialized. Since we are running FAP on pipe 0, and follow mode on pipe 1, the address width, address, CRC and payload length has to be set for these pipes. The Pipe 0 window, Figure 18, set the address width and the CRC, so these options are grayed out for the rest of the pipes, since these settings must be the same for all pipes. Refer to Table 1 for these settings. Note that the addresses used on the different pipes must be different from each other.

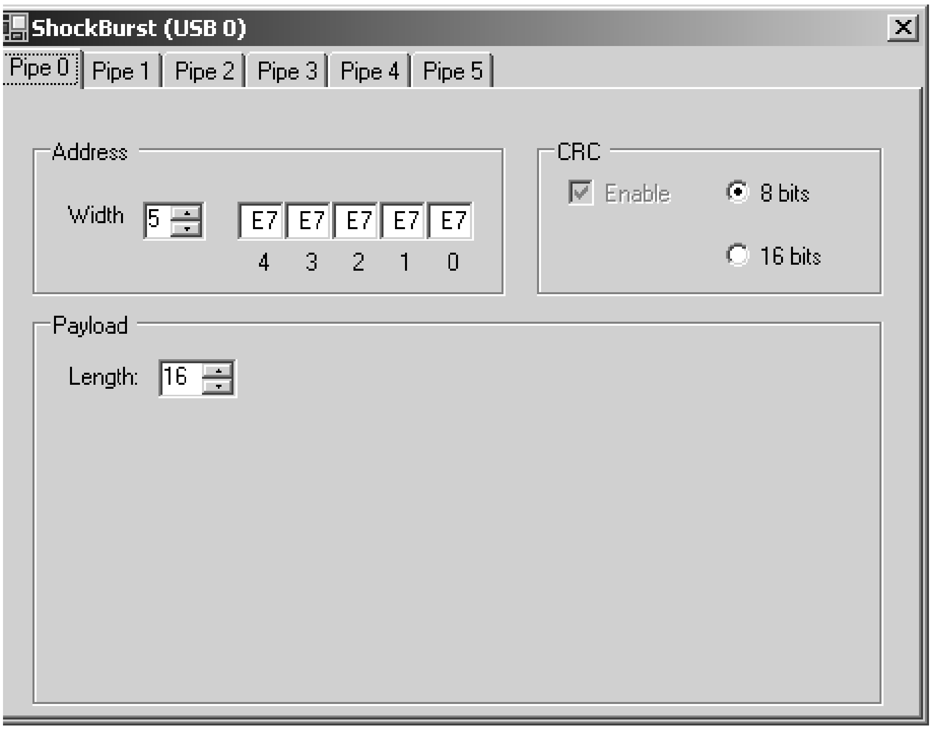

Figure 18: "Shockburst", RX device, Pipe 0, FAP mode

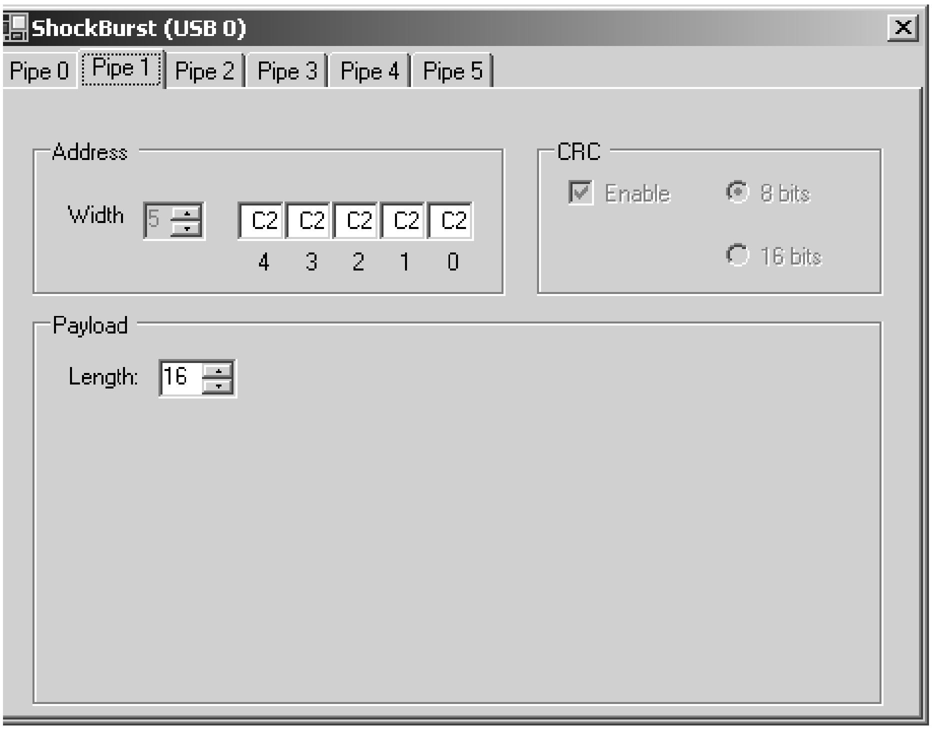

Figure 19: "Shockburst", RX device, Pipe 1, FAP mode

In this example, the address width, address, CRC and payload width is set to default:

Pipe#	Address Width	Address[hex]	Payload Length	CRC
0	5 bytes	E7E7E7E7E7	16 bytes	8 bits
1	Same as the master pipe	C2C2C2C2C2	16 bytes	Same as the master pipe

Table 1: "Shockburst" settings, RX device, FAP mode

The RX device is now ready to run, so pressing “Start Communication Mode” button will initialize this device, and start it up.

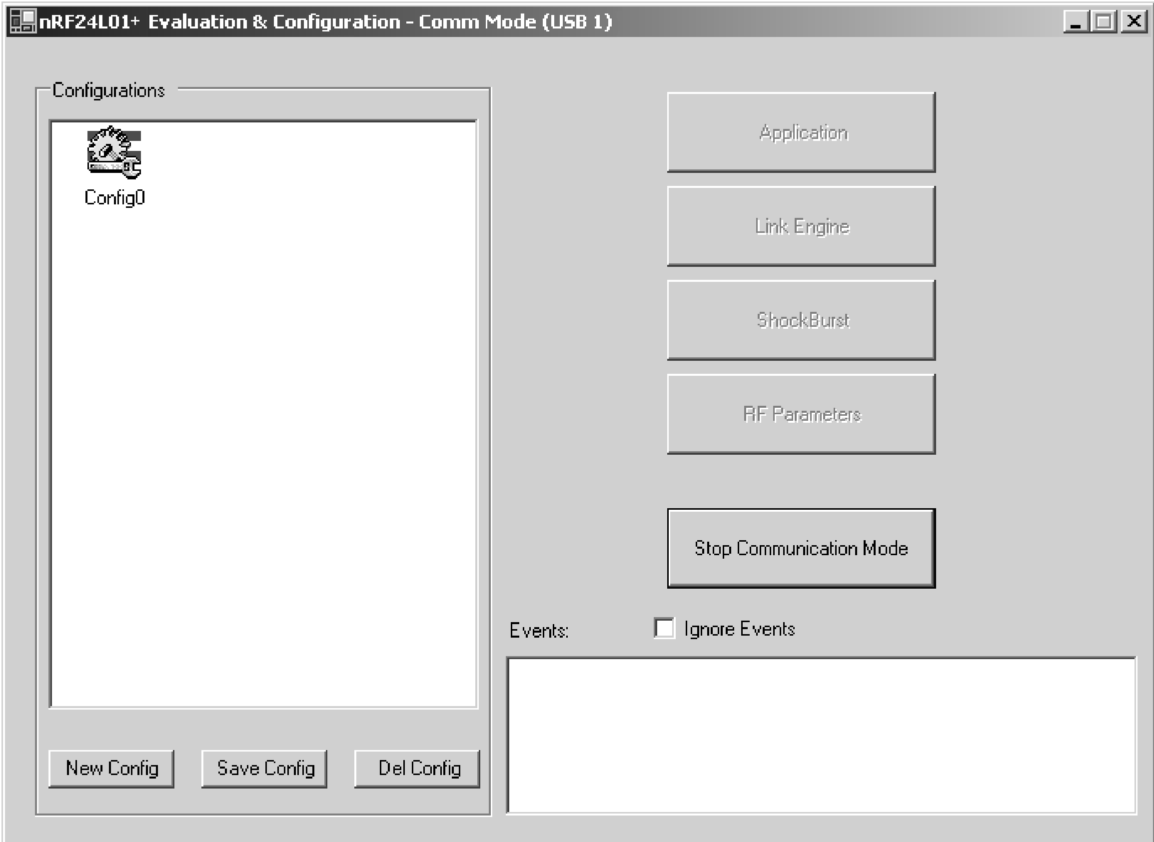

Figure 20: RX device started, FAP mode

Since the TX device is not configured yet, the RX device's FAP pipe will timeout, indicated by the "LED 3" and "LED 4" (see Table 4 for details) on the RX module, and no messages in the "Events:" window will occur. Leave this window open while configuring the TX device; this window will display event messages during run, after the TX device has been started.

The next chapter will setup the TX device(s), and start the "Frequency Agility Protocol Test".

TX DEVICE SETUP FOR FREQUENCY AGILITY MODE

Back to the main window, Figure 21, select the “USB 1” device and press the “Communication Mode” button and enter the “Application”.

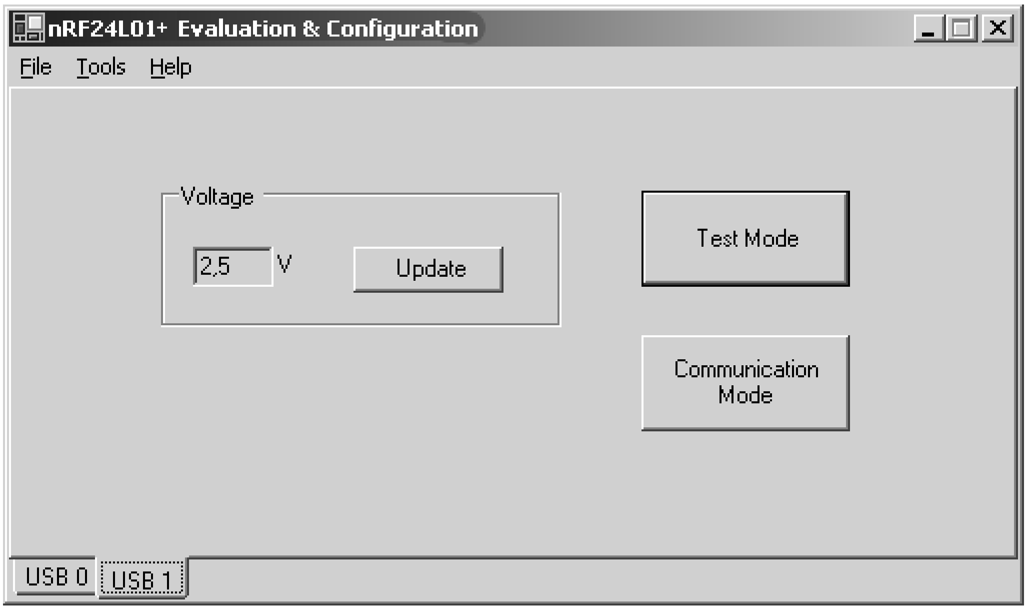

Figure 21: Main window, nRF24L01+EC Evaluation & Configuration

Make the selection as shown in Figure 22. These settings will make this a TX device running frequency agility, with a time interval of 5ms.

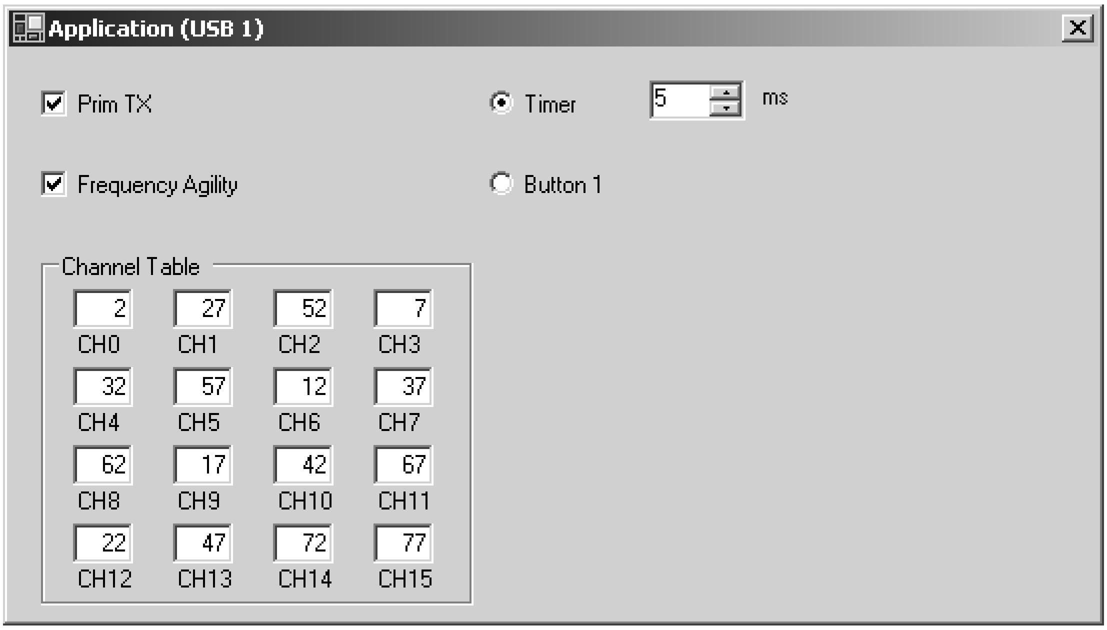

Figure 22: "Application", TX device FAP mode

The connection between “Timer” value for the TX device, and the “time before channel change if not heard from transmitter”, RX device, Figure 16 for this example is like this:

- The RX device will always wait exactly 8ms from last data reception, until the frequency-agility-timer times out, and it changes channel.
- The TX device which runs FAP tries to send a data packet every 5ms, and need to have 2ms margin to the RX timer in case of retransmissions.

This means that the minimum FAP timer value for the RX device, Figure 16, is calculated like this:

- $T_{TX} < T_{RX} - (N+1) \bullet t_{trans}$
- $N = number\_of\_retrans\_allowed(ARC)$
- $t_{trans} = startup\_time + time\_on\_air + retrans\_delay(ARD)$
- $time\_on\_air = \frac{1}{2}\mu s \bullet (preamble + address + flag\_bits + payload + CRC)$

For this example these parameter are set;

T_{RX}	N	startup_time	time_on_air	retrans_delay
8ms	3	130 µs	96.5 µs	250 µs+86 µs

Table 2: Parameters for T_{RX} calculation

With these parameters, the TX transmission time will be:
$T_{TX} < 8ms - 4*562.5\mu s$
$\mathbf{T_{TX} < 5.75ms}$

Since the timer values has a resolution of 1ms, we set this to **5ms** for the TX device, which is the closest to 5.75ms.

Now, moving to the “Link Engine”, Figure 23 we set the “Auto retransmit count” to 3, and the “Auto retransmit delay” to 250, according to the parameters below, Figure 23.

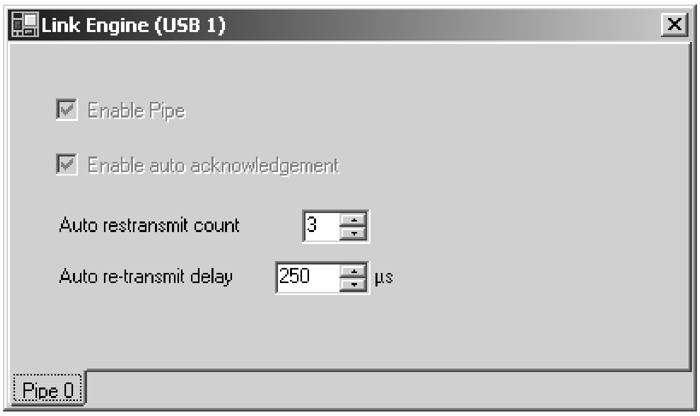

Figure 23: "Link Engine", TX device, FAP mode

The last setup we have to do is the “Shockburst”. Refer to the “Shockburst” for the RX device, the FAP pipe (Pipe 0), Figure 18. This TX device has to be set up with the same address width, the same address, the same CRC and the same payload length. These values, Figure 24, will be correct according to the RX device, pipe 0 (FAP pipe).

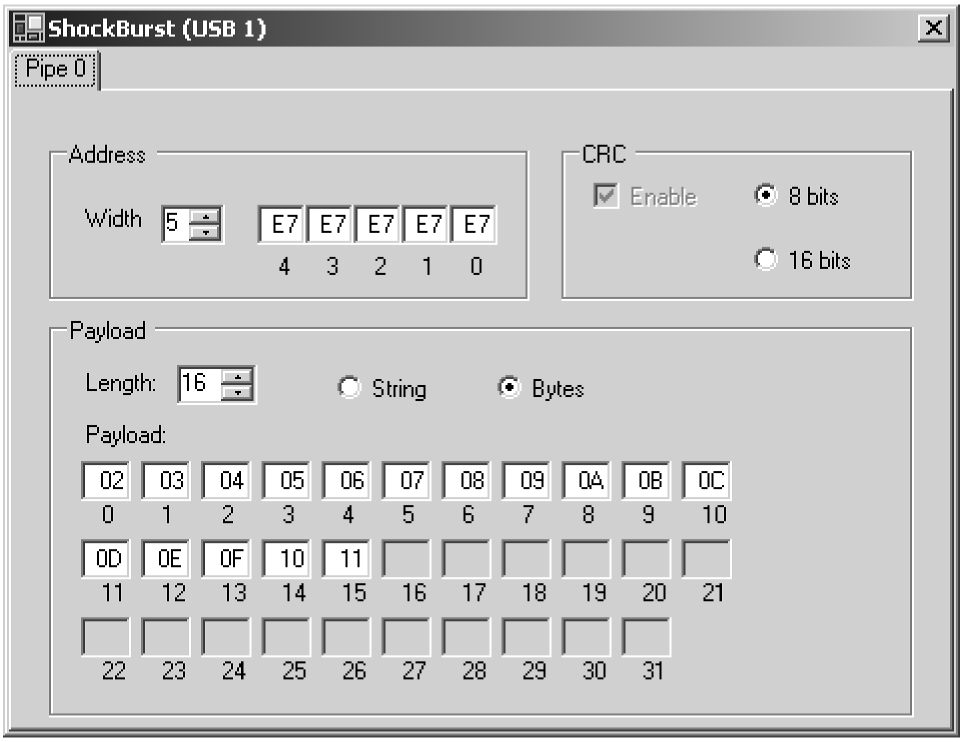

Figure 24: "Shockburst", TX device, FAP mode

This TX device is now configured, and ready for transmission. By pressing the “Start Communication Mode”, this TX device will start up and begin transmitting, running in frequency agility mode.

With the RX device started, up and running, a communication between the TX and the RX device will now be initialized.

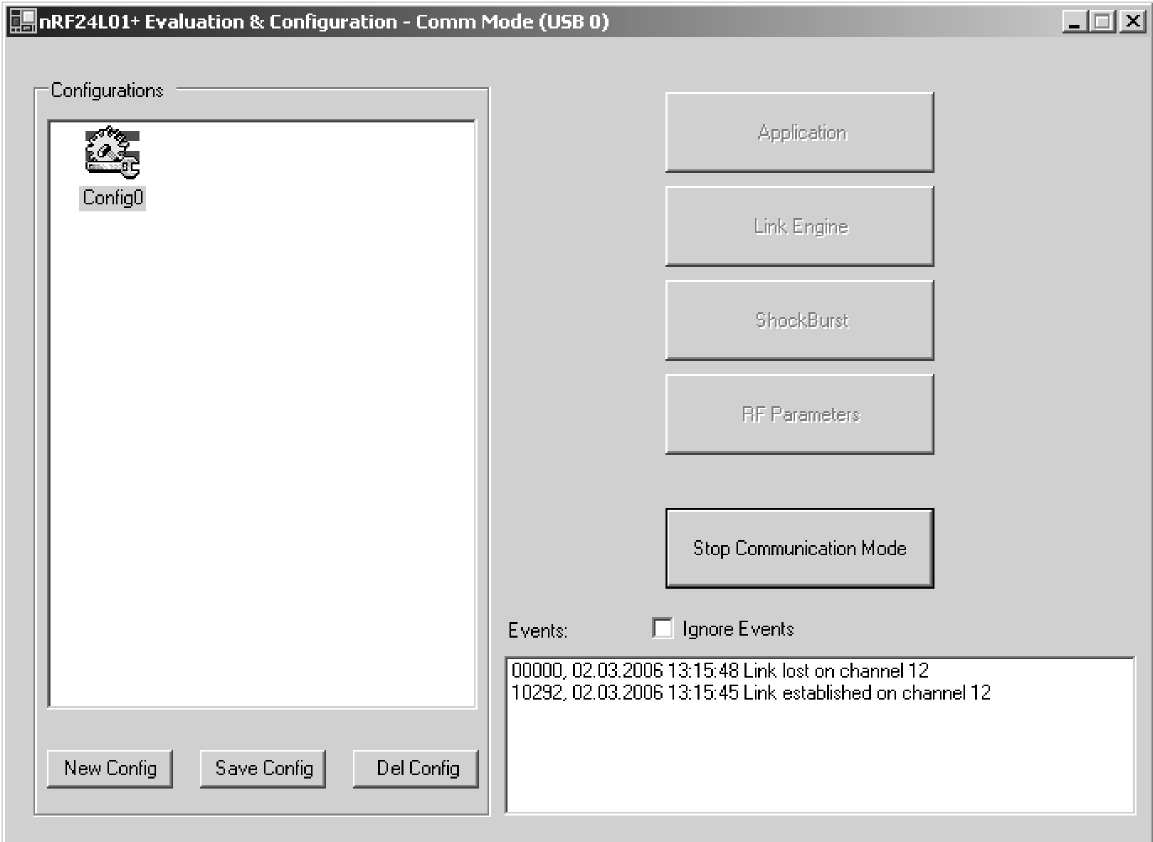

Figure 25: Communication initialized and running

The "Events:" window for the RX device (USB 0) will start printing Link Status messages. These messages have the format like follows:

Link delay[ms]	Timestamp[date time]	Link Status	Channel#
00000	02.03.2006 13:15:48	Link lost on channel	12
10292	02.03.2006 13:15:45	Link established on channel	12

Table 3: Events, link status format

- "Link delay" field displays in ms the delay from link loss, to next link establish.
- "Timestamp" field prints the Windows real-time clock, and date.
- "Link Status" field prints current event, link loss or link establish.
- "Channel" field print the channel the event occurred on.

For Table 3, the first event; **10292, 01.03.2006 17:16:16 Link established on channel 52** display a link delay of 10292ms, but this is of no meaning, since this is the time from the RX device was started, until the TX device was started. Link delay for event; "Link loss on channel…" will always display 00000.

During run, both the TX and the RX device will display status messages with their LED's.

LED messages for the RX device, in FAP mode		
LED#	**Action**	**Description**
LED 1	Blink	Reception of data on a FAP pipe.
LED 2	Blink	Reception of data on a pipe different from FAP pipe.
LED 3	Blink	Channel switching, i.e. FAP timeout.
LED 4	Blink	Frequency table wrapping, starting with channel in position CH0 again.

Table 4: Led status, RX device, FAP mode

LED messages for the TX device, in FAP mode		
LED#	**Action**	**Description**
LED 1	Blink	Data packet successfully transmitted.
LED 2	Blink	Trying to send one data packet.
LED 3	Blink	Channel switching, i.e. max retries reach.
LED 4	Blink	Frequency table wrapping, starting with channel in position CH0 again.

Table 5:Led status, TX device, FAP mode

This RX device has two pipes enabled, so this chapter will describe the setup of an additional TX device; in follow mode. For this TX device while it is running, make sure the batteries are installed and turn on the battery switch and unplug the USB cable. While the previous described FAP configuration is running, plug in a third module, with SW1 on the main board set to "2". This will make this the "USB 2" device.

Press the "Communication Mode" and then enter the "Application" for "USB 2".
Make these configurations for this device, see Figure 26. Select the "Button 1". This will configure this TX device for using the "Button 1" (B1) on the main board to sent data packets.

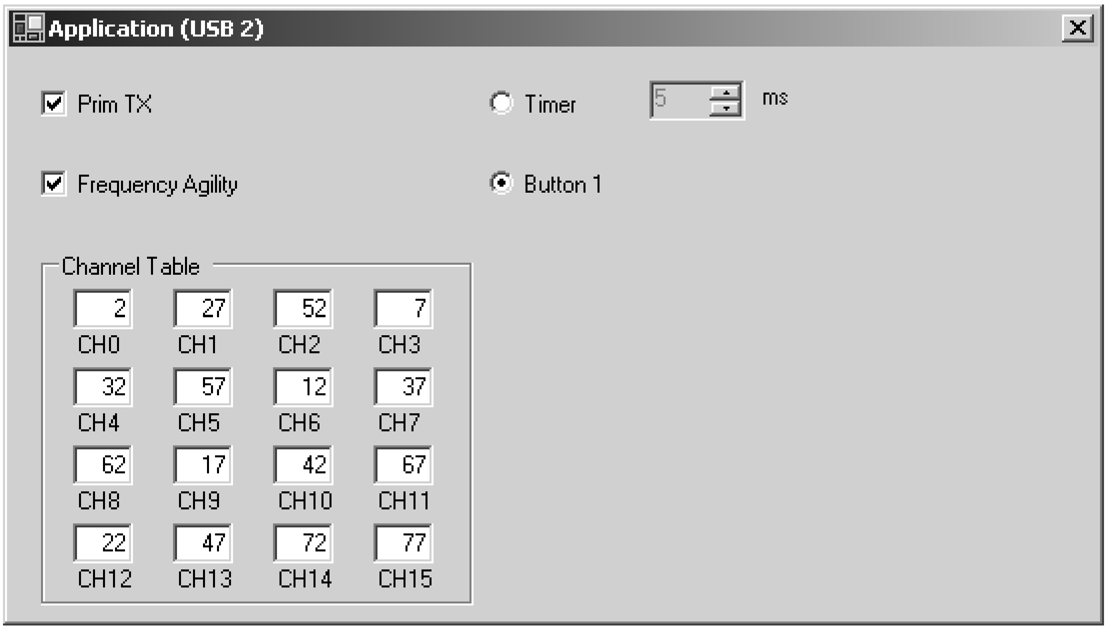

Figure 26:"Application", TX device, follow mode

Now, enter the “Link Engine”, Figure 27, and set the ARC and ARD values. Since the FAP pipe is using 250µs and 3 retransmit count, it is natural to use different settings for this device, since the same settings on both TX devices will keep collation with each other if they transmit a data packet on the same time.

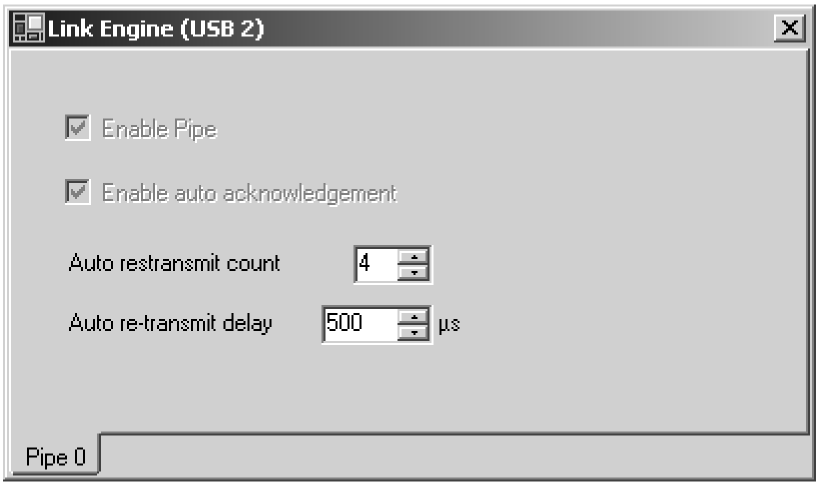

Figure 27: "Link Engine", TX device, follow mode

Enter the “Shockburst”, and set the same address as was set for pipe 1 on the RX device. Figure 28 shows this setting.

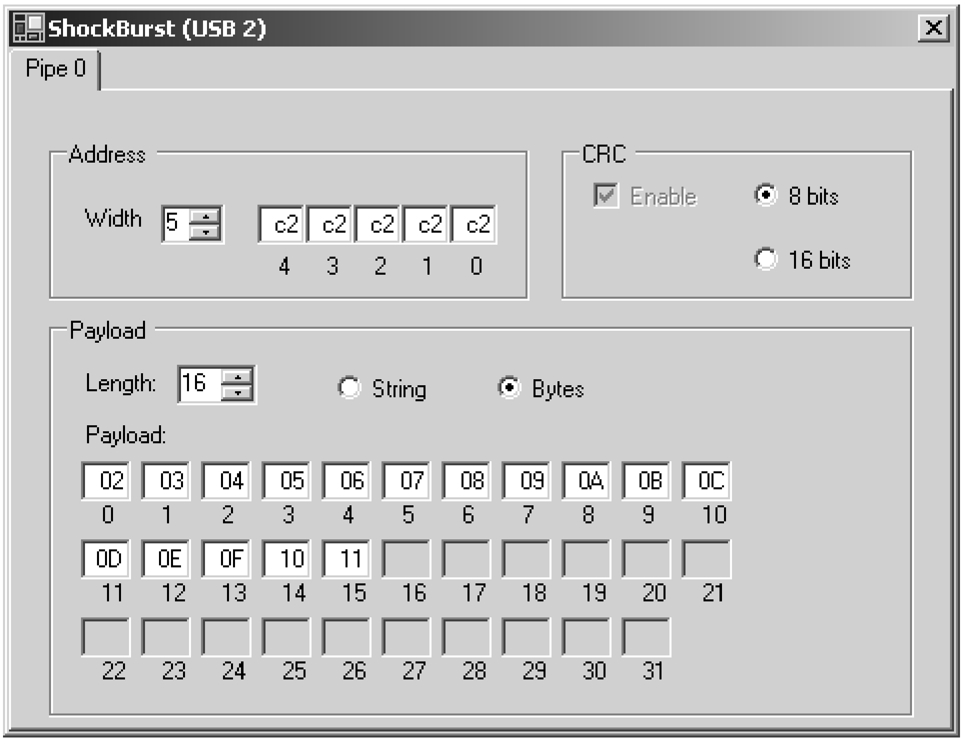

Figure 28: "Shockburst", TX device, follow mode

After making these configurations, press the “Start Communication Mode” for “USB 2”. This device is now configured to run as a TX device, follow mode, and to test this, data packets can be transmitted pressing “B1” on this device. This device also uses the same frequency agility table when changing channel, as for the FAP pipe. If a packet was lost, it will scan trough the table of a maximum of 3 times before it stop retransmitting the packet.

This device is now sending one single packet to the RX device, and is indicating this by the status LED’s. See Table 6 for details about the status LED’s.

LED messages for the TX device, in follow mode		
LED#	**Action**	**Description**
LED 1	Blink	Data packet successfully transmitted.
LED 2	Blink	Trying to send one data packet.
LED 3	Blink	Channel switching, i.e. max retries reach.
LED 4	Blink	Frequency table wrapping, starting with channel in position CH0 again.

Table 6:Led status, TX device, follow mode

Notice on the RX device that “LED 2” is blinking each time the “B1” button on this device is pressed, and the data packet from this TX device was successfully transmitted.

As already described, the “Events:” window for the RX device prints status messages during a FAP pipe application run. For the follow mode pipe, no events are printed, so the only status messages for this pipe is the LED’s messages, see Table 4 and Table 6.

As an additional way of measuring events, and delays on the radio link, a signal grid is available on the “BFB”, refer “nRF24L01+ Evaluation System nRF24L01+-EVSYSTEM” document. On this signal grid, oscilloscope probes can be attached, so the timing can be measured. The signals that are used are those connected to the status LED’s, so connecting to the pin 7, GPIO “LED 1”, you can measure the time between two successfully received packets. These pulses are active low, so a falling edge trigger should be set up for the oscilloscope. In the same way you can measure the time between channel switching, pin 11 and measure the duration between frequency channel table wrappings, pin 12.

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