Nordic VLSI ASA

nRF24xx Link Integrity

1. INTRODUCTION

To gain access to a world wide open frequency band, developers around the world are considering moving their RF applications from lower frequency (< 1GHz) dedicated or locally open bands to the world wide 2.4 GHz ISM band. With the nRF24XX RF component family from Nordic VLSI, also low cost applications can now easily use the 2.4 GHz band.

In comparison to lower frequency bands, the 2.4 GHz band is wide (83.5 MHz) and not divided into channels allowing for much higher data rates (wider frequency channels) and a variety of RF solutions to operate within the same frequency band.

A range of RF systems occupying the same frequency band is very different from the existing RF systems using narrow band channel and consequently low data rate. This rises questions on how to maintain your system integrity and communication stability.

This document guides you through the jump from a low frequency narrow band channel design to a low cost 2.4 GHz solution using nRF24XX from Nordic VLSI. It also addresses how to coexist with different interfering RF systems found in the 2.4 GHz band.

The rest of the document is made as a case study, where we look into how a 2.4 GHz mouse/keyboard solution with maximum reliability, link integrity and low cost is made using two nRF2402 transmitters and one nRF2401 transceiver from Nordic VLSI. This is an application that traditionally has utilized a narrow frequency band channel at 27 MHz.

The following requirements are set to the application:

1. Mouse and keyboard combo functionality
2. Low cost, one-way communication system
3. Minimal user configuration
4. Protocol ensuring RF system link integrity

The following issues will be covered:

- General discussion of system integrity in ISM bands
- Going from 27MHz to 2.4GHz
- How to design efficiently with nRF24XX
  - How to design the transmitters
  - How to coexist with other systems
  - How to design the DuoCeiver™ receiver
- Coexistence with other systems
- Current consumption

2. SYSTEM INTEGRITY IN ISM BANDS

When venturing into the 2.4 GHz ISM band also containing known wide spread and powerful systems like wireless LAN (WLAN) and Bluetooth, quality-of-service and system integrity are issues of great concern.

Traditionally the RF specification of the device itself (utilizing SAW filters etc.) and limiting the number of operators (licensing) in a band has carried the main burden in accomplishing this.

But in open bands, such as the ISM, there can be an unlimited number of devices and systems in operation. RF protocols that can cope with the occasional collision while maintaining system integrity become increasingly important.

In addition to the security that is inherent in the RF package itself (addressing and CRC), system integrity is improved by the following:

1. Acknowledge of received packages, retransmission if transfer failed.
2. Dynamic frequency allocation
3. Frequency jumping / spread spectrum
4. Multiple transmissions of the same data

Before considering what should be implemented, there is one major decision that has to be made that will dictate what options you have:

1. Two-way communication using RF transceivers
2. One-way communication using a transmitter-receiver solution

To be able to implement the protocol features 1-3 listed above you MUST have two-way communication utilizing RF transceivers.
If you do not have two-way communication you effectively remove the feedback in the system and it becomes impossible for the system to manage itself and verify that the communication in fact is OK.

Two-way systems are generally more expensive than one-way systems, the tradeoff here is clearly a price-performance issue.

Due to cost requirements many customers specify that only a one-way keyboard/mouse combo system without user configuration is acceptable. In the next section such a system is presented exploiting all the features the Nordic VLSI nRF24xx devices gives.

3. GOING FROM 27 MHz TO nRF24XX

When going from the traditional 27 MHz solutions to the Nordic VLSI nRF24xx 2.4 GHz solution, not only is the leap in frequency large, the change in design approach and thinking should also be considerable.

3.1. Standard 27 MHz system

In the low data rate 27 MHz systems, each node in a system has to stay on the air virtually all the time while the equipment is used because the transfer time of one RF package are in the same order as the up-date rate of the mouse/keyboard.

Example:

RF data rate 9.6 kbit/s
Packet length: 100 bits
Typical mouse up-date rate: 10 – 15 ms

To transfer one package will take:

$$T_{tr} = \frac{100\,bit}{9600\,bit/s} = \underline{\underline{10.4\,ms}}$$

A new package from the mouse is in other words ready for transfer as soon as the last one is finished. Since the system has to stay on the air for as long as it is in use, the only thing separating two devices or systems in this case is the frequencies they operate at. Narrow band channels with strict requirements to channel selectivity and RF blocking is hence of vital importance since this is the only thing ensuring your system integrity.

3.2. Nordic VLSI nRF24XX System

In the Nordic VLSI nRF24xx devices, the on-chip ShockBurst protocol engine enables the same low speed, low cost micro controller running a 27 MHz system to handle a 1 Mbit/s RF link.
The mouse from the example above will now use only:

$$T_{tr} = \frac{100\,bit}{1\,Mbit/s} = \underline{\underline{100\,\mu s}}$$

It is transferring the same amount of data as previously, but in a significantly reduced timeframe. This means that your RF channel actually is free and can be used by others for 10.3 – 15 ms between each package you need to transfer.

This major drop in time on the air of course reduces the risk of being jammed by other systems significantly. Since most of the other operators in the 2.4 GHz band also operate on similar data rates, no single channel is occupied for long periods of time.

If a low data rate system is introduced at 2.4 GHz this will give rise to other problems especially for that system itself we will discuss this further later in the document.

Due to the low cost and high data rate offered by the nRF24xx devices in ShockBurst mode, a system based on these devices is fundamentally different compared to a narrow band, low data rate system. It is important to take full advantage of the high data rate both to minimize risk of jamming, prolonging battery lifetime and keeping the rest of the design low cost and simple. Using nRF24XX will make the total solution smaller, easy to manufacture and will offer what the end user perceives as "good range and performance".

The new way:
While keeping the same low cost solution in the rest of the system the rules of designing the RF front changes:

> **27MHz:** low data rate = long time on air = collisions likely = strict frequency separation needed.
> **nRF24xx**: high data rate = short time on air = collisions unlikely = time sharing on one frequency partly replaces the need for the strict frequency separation.

The nRF24XX solution will also offer a possibility of manufacturing with high yield, using a small low cost PCB antenna with a good range. The direct consequence of this is that the number of complaints and returns from dissatisfied end users complaining about "not working" (lack of range?) will be eliminated.

4. HOW TO DESIGN EFFICIENTLY WITH NRF24XX

In this section we will present a wireless mouse keyboard combo solution based on Nordic VLSI nRF24xx devices. In the next sections, we look at how the system will cope with interference from other systems, and what current consumption and battery lifetime can be expected.

4.1. How to design the transmitters

The Nordic VLSI 2.4 GHz devices for one-way communication are the nRF2402, 2.4GHz transmitter, and the nRF24E2. The nRF24E2 consists of a nRF2402 transmitter, an 8051 micro controller and an 8 channel, 10 bit ADC embedded on one chip. By using the nRF24E2 the external micro controller can be removed resulting in a single chip solution. Remember that any references to micro controller functionality in the rest of this document also can be done using the nRF24E2 embedded 8051 controller.

For the following discussion the nRF2402 is used as an example.

With one-way communication and no user configuration several parameters must be set prior to shipping the systems. This requires that mouse, keyboard and receiver are paired in production.

In a one-way system, the following parameters must be set in the design phase:

1. RF channel
2. Output power
3. Other RF protocol parts such as addressing, CRC length and payload length
4. Up-date rate (time between packages, default 10 ms)

We will explore how such a system can be made, how it will perform and what system integrity we can expect.

Since the peripheral units is battery powered and the receiver is fitted on the PC with ample power available, minimizing the current consumption in the peripherals is important. By activating the RF front end for a short time as possible as seldom as possible the average current consumption is minimized.

The receiver can be assumed to receive continuously, this means that the transmitter can send its packages whenever it has a new sample for the PC. A timer in the mouse/keyboard manages this timing.

4.2. The RF packet

All the communication is split into packets. The RF packages consist of 4 bytes payload for the mouse and max 8 for the keyboard. Since the only difference is the payload length, the mouse protocol is used as an example in the rest of this section.

In addition to the payload the RF packet must have some overhead to ensure correct communication:

1. Preamble (8bit) to initiate the RX demodulator upon the start of the package.
2. RX address (up to 40 bits), The 'name' of the receiver the packet is intended for
3. CRC (8 bit): cyclic redundancy check, ensuring that bit errors in the packet is detected.

The numbers in parenthesis, is the number of bits used in the nRF2402 ShockBurst protocol. The packet length will hence be 8+40+32+8 = 88 bits.

4.3. The ShockBurst principle

The nRF24xx ShockBurst protocol engine handles the protocol and high speed part of the RF communication.
To send a package the micro controller has to:

1. Set nRF2402 CE high
2. Clock in the address of the receiver and the payload section of the packet.
3. This is done on 3 wire serial interface on a speed decided by the micro controller. The nRF2402 current consumption during this operation is 25uA.
4. Once the address and payload is clocked in, the micro controller sets CE low, this initiates the ShockBurst engine which handles the rest.
5. The ShockBurst engine calculates CRC and adds preamble and CRC to the data clocked in.
6. The RF front end is powered up (power up delay 195 us)
7. The packet is sent (1 Mbit/s = time on air: 88us)
8. The nRF2402 automatically returns to stand-by.

The nRF2402 can now sleep (stand-by or power down) until the next package is to be transmitted.

If the micro controller is connected to a nRF2402, the data between the micro controller and the nRF2402 can be kept at 9.6 kbit/s, while the data rate on the air is 1 Mbit/s. This means that both the time-on-air and the average current consumption of the RF front end are divided by the factor 9.2ms/88us = 105. This is illustrated in Figure 4.1, where the grayed out area is the time on air with peak TX current consumption.

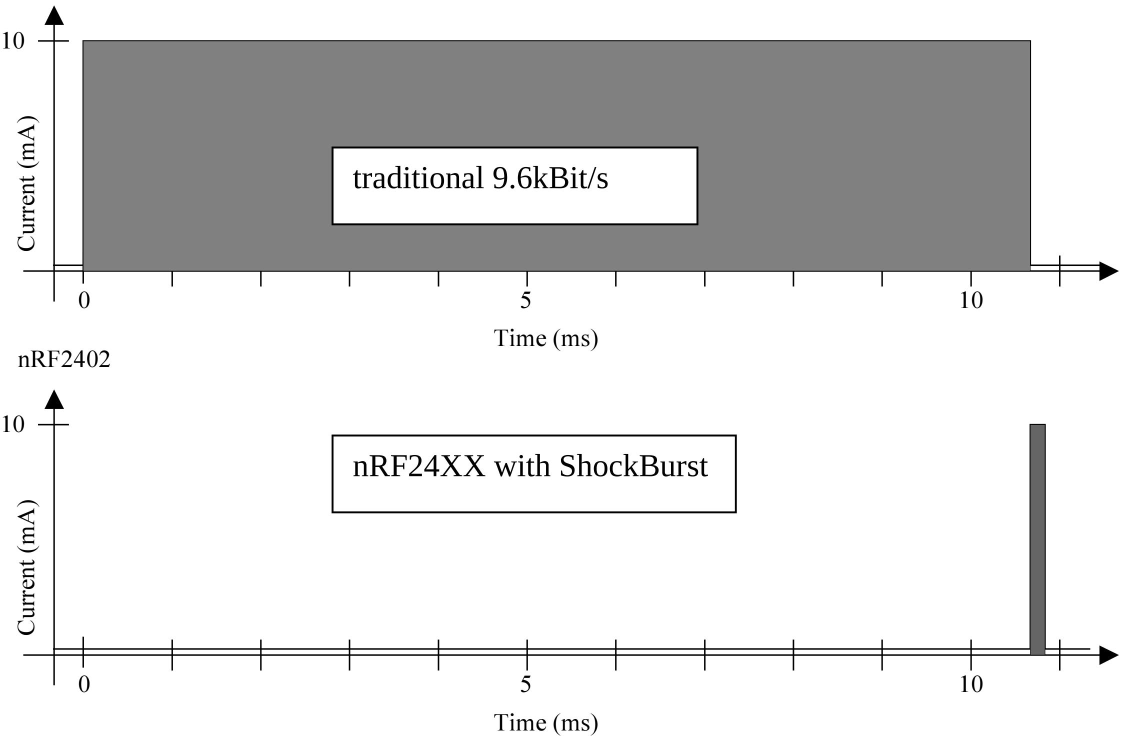

Figure 4.1 Time on air and current consumption 9.6kBit/s vs. nRF2402

The data rate alone makes the nRF2402 0.095 times less likely to be jammed, and reducing the average current consumption 105 times compared to a traditional system runing at 9.6 kbit/s.

While the nRF2402 is on the air the neighbour channel selectivity and the RX blocking in the receiver in the system decides the immunity towards other transmitters, just like in any other system.

Occasional jamming results in loss of a packet and it is down to the RF protocol to ensure that the system does not suffer from these occasional losses.

4.4. How to design the DuoCeiver receiver

As the receiver in the system you should use the nRF2401 transceiver or nRF24E1 which is a device similar to nRF24E2 but with the nRF2401 transceiver instead of nRF2402 embedded. It has the same 8051 micro controller and the same ADC.

This document uses the nRF2401 for all examples.

On the PC side where there is ample power, you can leave the receiver on permanently.

ShockBurst receive:

1. After configuration to receive, CE is set high to activate the device
2. After a 200us power up delay the receiver is up and running.
3. The ShockBurst protocol engine interrupts the micro controller only when a package with valid address and correct CRC is received.
4. The micro controller can then clock out the payload; The ShockBurst engine strips of the entire overhead in the RF protocol (preamble, address and CRC).
5. Clocking out is done on a 3-wire interface and at a speed set by the micro controller.

Since the ShockBurst engine handles all the data recovery routines the receiving micro controller doesn’t have to spend resources on checking incoming messages that is not intended for it. The ShockBurst feature with address and CRC decoding significantly reduces processor computing power and memory requirements, a major reason why low cost, low power micro controllers can be used with the nRF24xx devices.

4.4.1. DuoCeiver™

Since there are two independent transmitters in the same system (mouse and keyboard) it is impossible to guarantee that packages from them never will collide when occupying the same RF channel. To guarantee this Nordic VLSI has implemented the DuoCeiver function in the nRF2401. When this option is enabled the nRF2401 works on two separate RX channels fixed 8 MHz apart.

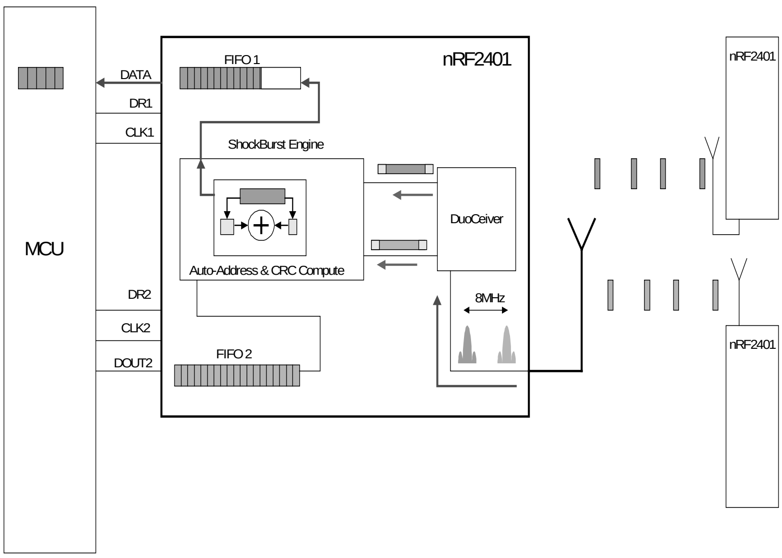

Figure 4.2 nRF2401 DuoCeiver

Both RX channels have all ShockBurst features and have separate interrupt lines and I/O interfaces (Figure 4.2).

If you configure the keyboard nRF2402 to send for instance on RF channel 2 (2.402 GHz) and configure the receiver to the same channel, the DuoCeiver feature opens up another receiver 8 MHz above the first (i.e. @ RF CH10, 2.410 GHz). If you configure the mouse to this RF channel, the nRF2401 on the PC side will be able to receive packets simultaneously from both mouse and keyboard through the same antenna.

Using DuoCeiver you ensure no interference between the keyboard and the mouse.

5. COEXISTING WITH OTHER SYSTEMS

To make a robust system, it is important to understand how other systems operating in the 2.4GHz bands affect your system. How to handle collisions depends on what kind of system is interfering with the transmission.

We divide the different systems into 4 categories:

1. Direct spread spectrum devices (WLAN)
2. Burst and frequency jumping systems (nRF24xx and Bluetooth)
3. Single channel, low data rate systems.
4. Multiple systems of same type (Multiple nRF24XX Combo systems)

5.1. Wireless LAN

Powerful systems with large amounts of data being transferred like WLAN use direct spread spectrum to spread the RF energy across a wide frequency range. One WLAN utilizes a 22 MHz wide channel and the energy density towards the outer reaches of the direct sequence transmission is down to at least –10dBm (according to FCC guidelines). Furthermore, any physical separation between a nRF24XX device and WLAN will reduce the received RF energy from the WLAN. The inverse square law dictates that 6dB of output power is lost with each doubling of distance from the transmission source, typically the location of say, a WLAN access point will be mounted high up and well separated from the nRF24XX link.

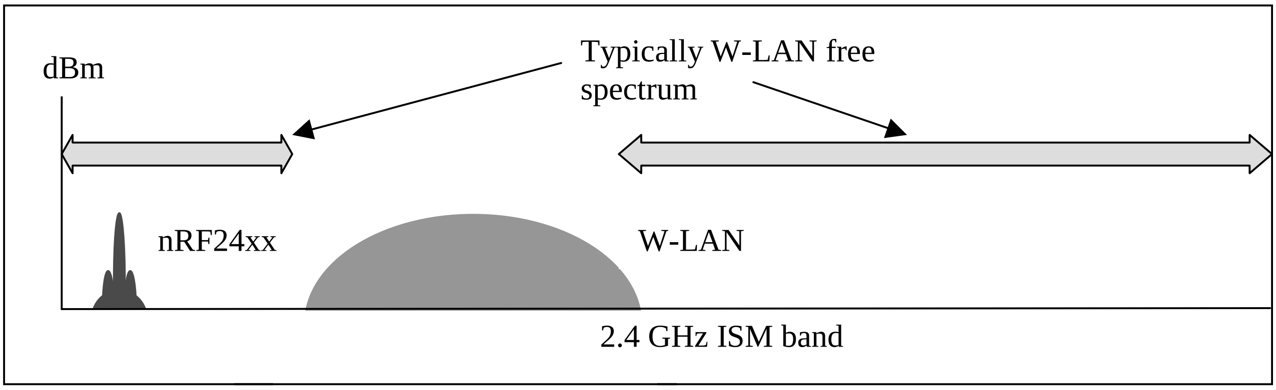

Figure 5. 1 nRF24xx coexisting with WLAN (measured at receiver)

It can be seen in figure 5.1 that typically, only one W-LAN network will be physically co-existing in any particular area. This means that 75% of the ISM band is W-LAN free, this equates to 60+ channels free for nRF24xx operation. Fig 3.2 shows that at the outer channels utilised by the W-LAN transmission there is a sharp fall-off in signal strength and therefore the nRF communication may well be able to operate in this region with only some degradation of system sensitivity as a result.

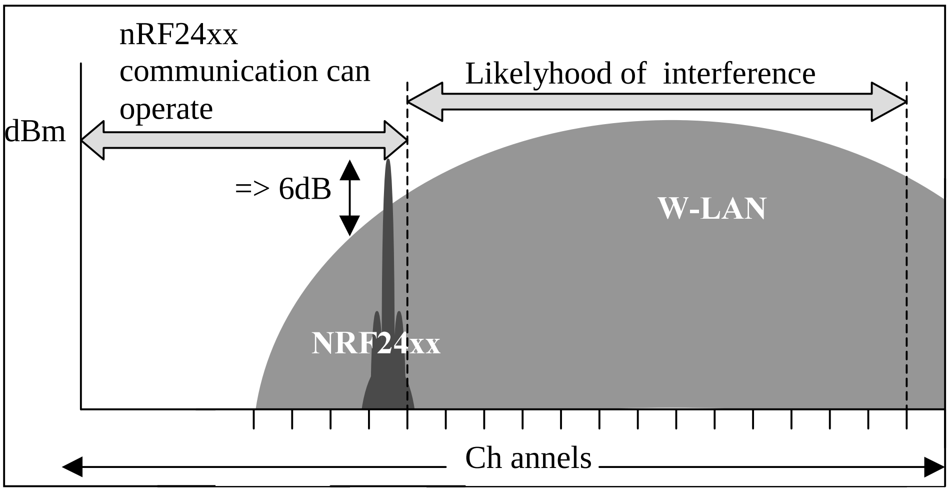

Figure 5.2 nRF24xx operating at outer limits of W-LAN spectrum

5.2. Bluetooth

Bluetooth is today most common system in the 2.4GHz space and the Nordic VLSI nRF24XX devices share the same basic radio architecture. The difference is Bluetooth's need for a complex protocol engine increase the power consumption and cost dramatically.

The following example show how the nRF24XX coexist with the Bluetooth, which jumps among 79 channels, but only stays on one channel for 625 us (Figure 5.3).

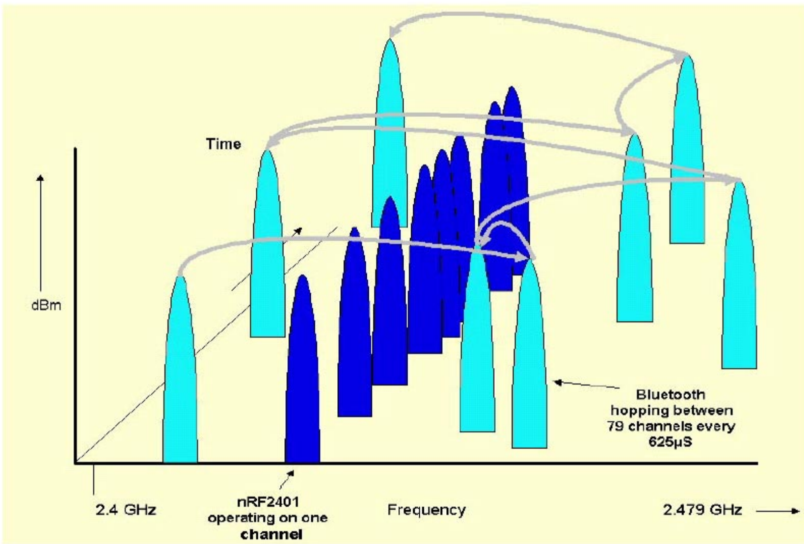

Figure 5.3 nRF24xx coexisting with Bluetooth

If a collision occurs at the channel used by the nRF24xx system, we know that the channel will be free again for the nrF2402 to re-transmit the package within 625 us.

The longest one has to wait is when a Bluetooth device starts to transmit just as one nRF2402 packet is finishing, we then know that the channel will be occupied for up to ~625us. If we wait beyond this before re-transmitting the channel is likely to be vacant again. So, by sending each package from the nRF2402 2 times > 625 us apart one of them will get across. This is show in Figure 5.4.

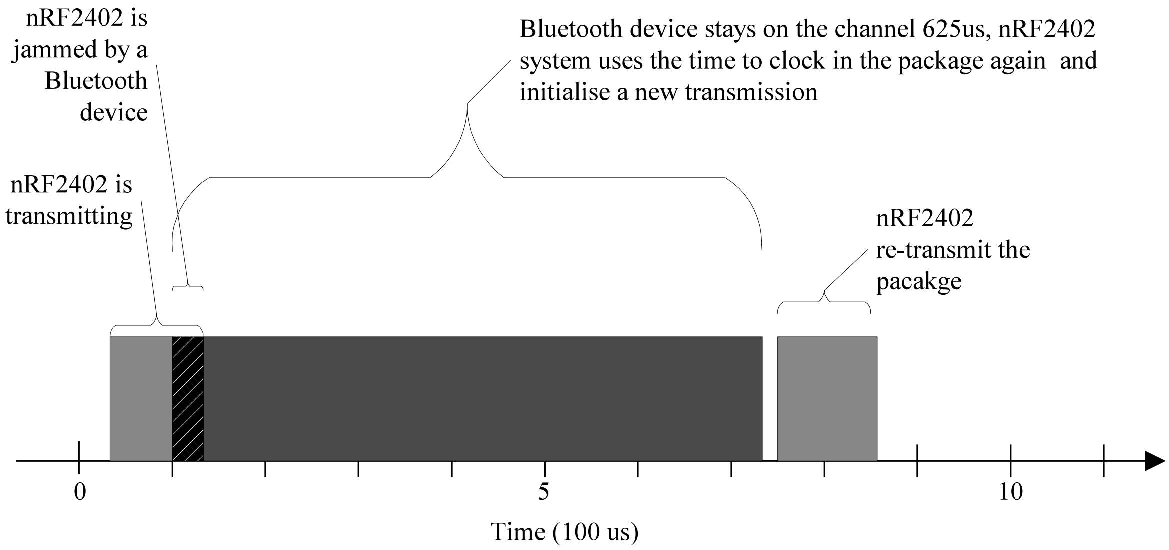

Figure 5.4 nRF2402 jammed by Bluetooth

What does this mean for the mouse SW?
To re-send the package the nRF2402 must

1. Clock it in again
2. Wait for the stand-by to TX delay (195 us)
3. package is sent

This means that you have at least:

$$625\mu s - 195\mu s = 430\mu s$$

to clock in the address and payload of the package again.
This section is 72 bits long. If you start to clock in a new package immediately after the first one is finished, you can use a data rate of up to:

$$\frac{72 bit}{430\mu s} = 167 kbit/s$$

When you have finished clocking in and the nRF2402 is finished settling the channel it will be free to use again.

If the collision occurs with a different nRF24xx device we know that it will be off the air within 262 us (max length ShockBurst package), which enables you to re-transmit even faster. By sending each packet twice, you will avoid interference with Bluetooth and other frequency jumping devices.

5.3. Other Single channel 2.4GHz systems

In a one-way combo system the receiver can detect a fixed frequency low data rate system, but there is no way to tell the pure transmitters that they are jammed and should change the TX frequency.

The positive side is that transmitters which are sending almost continuously on one channel are required to have a RF output power less than 0 dBm, so the influence is limited in space (distance) and is for the main part handled by the RF blocking in the nRF2401 receiver.

The solution for the end user if a problem is detected is physical separation between devices, or a manual way of setting a new frequency.

The low data rate systems themselves are on the other hand vulnerable to interference from a multitude of systems because the long time they stay on the air. Even with RSSI to detect any traffic in the channel they don't have any guarantee against a second device suddenly appearing on their channel during their transmission. A Bluetooth system would jump to a different channel and complete its communication well before the low data rate device has finished its communication only to find that it has been corrupted.

Furthermore RSSI or other means of detection of free channels is only of real use if your turn around time is a fraction of the time you <u>and others</u> are on the air. If the turn around time is too long another device might have moved in. Remember that the nRF2402 will stay on the air for only 88us.

5.4. Multiple systems of same type

As previously discussed the DuoCeiver feature enables a mouse/keyboard combo that can operate without collisions between them.
When multiple nRF24xx mouse/keyboard systems are operating within a confined area the high data rate and ShockBurst keeps the probability of collisions low, even if the combo systems share the same frequencies. Each mouse-keyboard system is active on the air in one channel for only 1.75% (2*88us/10ms) of the 10ms up-date period of the peripherals.

5.4.1. Limit transmission range

To establish how many systems that actually might interfere with each other we must take look at the line of sight ranges one achieve, what the data rate and protocol gives and what obstacles means to a 2.4 GHz link.
Unlike 27 MHz systems, the range achievable with 2.4 GHz solutions is more confined firstly because the transmission losses in air is much greater on 2.4GHz and secondly because 2.4 GHz doesn't travel well through walls etc.

Signals from a 2.4 GHz system in the next room is generally so attenuated that it can't make problems for you. This statement is based more on experiences and empirical research in the business rather than straightforward mathematics. Mathematical models trying to cover this will by no means be straightforward in any case.

So if all systems outside a room can be ignored one is left with the systems in the same room. This is of course not a strict rule, but applies so widely that also in other systems (like Bluetooth) it is said that "one system covers one room".

If we take an open office space as an example, mouse-keyboard systems can be placed alongside each other without significant obstacles between them. To keep the math simple we say that each workstation (each system) occupies 1 m^2, meaning that the distance from the TX to RX in one system is below 1 m and the next is no closer than 1 m away. These factors can of course easily be scaled.

There are 3 factors that isolate the different systems from each other:

1. Physical distance (range of each system)
2. Receiver selectivity (RF blocking)
3. Time on air for each system.

5.4.2. Line of sight range

If the output power for each transmitter is high it will of course cover a large area which again put stricter demands on the channel selectivity in all of the receivers in the area.

Since the sensitivity of the nRF24xx devices are fixed for a given data rate, the range of each system is dictated by the output power of the transmitter and the gain of the TX and RX antenna respectively.

With ¼ wave PCB whip antenna gain of -5 - -10 dBi you can achieve an effective radiated power (ERP) from the transmitters of < –5dBm @ 0 dBm TX output power and a receiver sensitivity of > –75 dBm. In other words the free space loss (FSL) in the system is < 70 dB.

Free space loss is given by:

$$FSL = -20LOG\left(\frac{\lambda}{4 \cdot \pi \cdot R}\right)$$

Where λ is the wavelength at 2.4 GHz and R is the maximum theoretical line of sight range obtainable. This translates to:

$$R = \frac{\lambda}{4 \cdot \pi \cdot 10^{\frac{-FSL}{20}}} = \frac{0.125}{4 \cdot \pi \cdot 3.16 \cdot 10^{-4}} = 31.5m$$

31.5 m is a much longer range than is needed or feasible in such systems. By reducing the output power to –10 dBm, you get a FSL of 60 dB and consequently a LOS range of ~10 meters. This gives you a range that is not to long while keeping some head room for losses caused by small obstacles like tables or the PC/screen itself.

5.4.3. Receiver selectivity

If two transmitters with the specifications from the last section goes on the air on the same channel at the same time, the unwanted one must be 6 dB (co-channel rejection, table 4, nRF2401 data sheet) weaker than the wanted one. With an increase in FSL of 6 dB for each doubling of range, this means that the distance from the unwanted transmitter must be 2 times the distance from the wanted. In other words if the distance between the mouse and the receiver on your PC is 0.5m the other mouse must be > 1 m away from your receiver. This is illustrated in fig.5.4.2. Here TX1 is a communication system with RX1, TX2 communicates with RX2, TX3 communicates with RX3 etc. As long as the circle of clear communication is maintained (has a diameter that is twice the distance between the TX device and the RX device) the nRF24xx systems will not interfere with each other.

If the two systems in question operates on neighboring channels, the 'hostile' system just needs to be further away than your own transmitter (neighbour channel selectivity (+/- 1 MHz)= -1 dB, table 4, nRF2401 data sheet).

If the two systems are 3 channels (3MHz) apart the hostile systems transmitter can be placed 16 times closer to your receiver than your own transmitter without interfering with your wanted communication.

So in the office environment example, the only systems that can interfere with each other are the ones right next to each other. The second system down the row will be sufficiently weak not to interfere even if they send in the same channel at the same time.

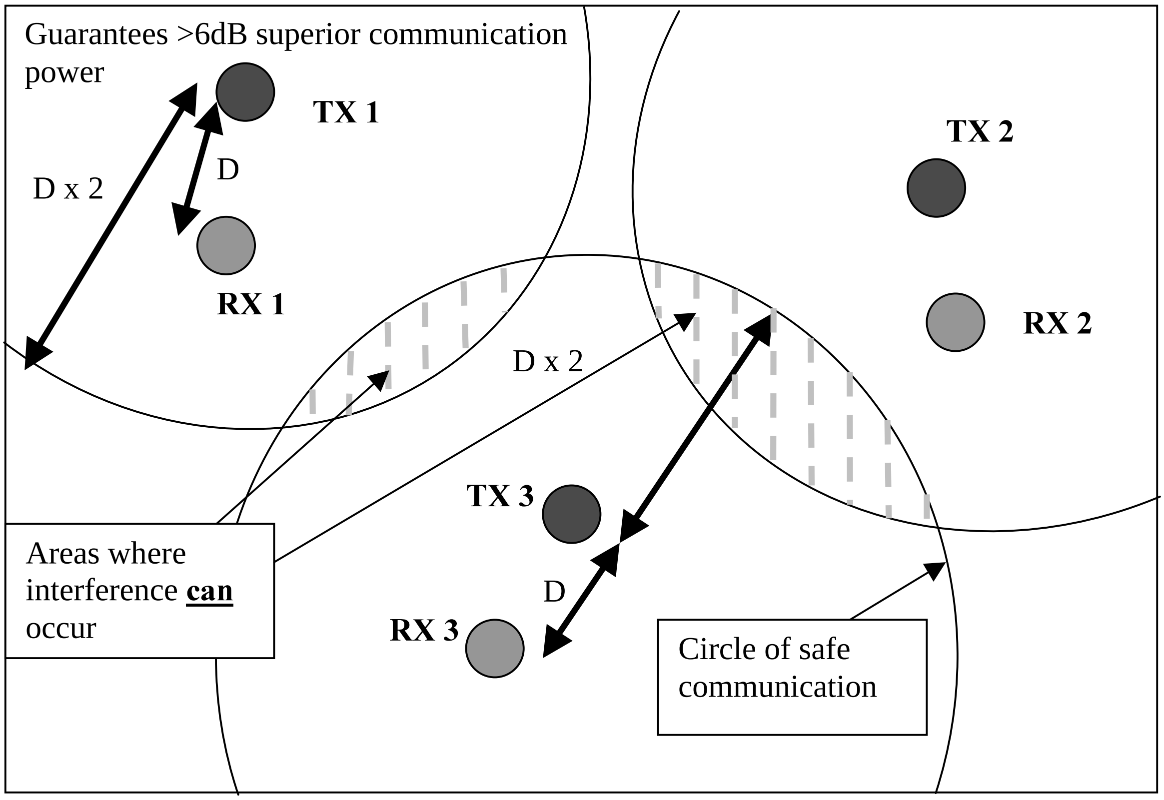

Figure 5.5 Interference reduced by physical separation of 2x system comm's distance

5.4.4. Time on air

Remember that the interference 'problems' described in the last section only will occur if the transmitters go on the air at the exact same time. In a 2.7 MHz system, where the different transmitters are on the air almost continuously this is the crucial make or brake point. But in a nRF24xx system you also benefit from the short time on air. 1 Mbit/s data rate, offered by the nRF ShockBurst feature, reduces the active time on air for each mouse (same for keyboards in their channel) system to 1.75%.

If we imagine a group of tables or two long rows facing each other, we have on system one on each side and 3 across. If we look at the office environment the maximum number of systems that are in range to interfere are 5.

We can assume that the different systems are completely independent so the time they occupy the RF channel is a stochastic variable. So, the probability of a collision is how likely it is that the channel is occupied by one of the other systems, or:

$$P_{col} = n \cdot \frac{T_f}{T_{ud}}$$

Where:

P_{col} : probability of collision
n: number of interfering systems
T_f: The time each interfering system occupies the channel
T_{ud}: The period of the transmissions

With the numbers found above using retransmit this is:

$$P_{col} = 5 \cdot \frac{2 \cdot 88us}{10ms} = 0.088$$

So the higher data rate reduces the chance for collisions from 1 (9.6 kbit/s all systems on the air continuously) to only 0.088.

Note1

This probability is valid only when all the systems are active, this means that all the 6 users in the area must operate (push) their mouse continuously. As soon as one lets go of the mouse it can go to sleep and hence the probability will drop further.

For example: In battery lifetime calculations IBM use an active time (i.e. mouse physically in use sending every 10 ms) of ~20 min/day, which translates to 1.3% active time. This reduces the low probability already achieved with the high data rate by another factor of a similar magnitude. If the use of the mouse is seen as a stochastic variable as well, the probability now drops to 0.0012.

Note2

One issue is still not resolved: If two nRF24xx one-way mouse-keyboard systems collide, the packets will be lost. With both systems running the same re-transmit timing both the packages will be lost because if the first packets collide so will the second.

Implementing a random delay in the re-transmit timing solves this problem. I.e. the time between the transmitter sending packet 1 and 2 is not only dictated by the time a Bluetooth devices might occupy the channel, but is also varied to avoid any possibility that both packages sent are corrupted by collisions with another nRF24xx system running the same protocol.

5.4.5. Multiple frequencies

Finally by shipping systems randomly programmed to for instance 6 different frequencies you will reduce P_{col} with another factor because the 5 interfering systems described above now also is spread in frequency. The probability for collisions now can be anywhere from 0 (all 6 systems on different frequencies) to the same as above (all systems on the same channel) it is all down to how randomly the systems are shipped and placed in the final office environment.

5.5. Summary of coexistence with multiple systems of same type

The described nRF24xx Mouse/Keyboard combo system using only one channel for mouse communication (+ the DuoCeiver feature for the keyboard) have a very little probability of interference. Based on the co-channel rejection we have shown that in a typical environment, the maximum number of system that can interfere with each other is 6.

With 6 systems the probability for RF collisions is only: 0.088 + 0.013= 0.0012. This is based on use of nRF24xx ShockBurst, IBM's 'operational time of mouse' estimates and assumes that one system can see any channel occupancy (time on air of the interfering systems) as a stochastic event.

By programming mouse/keyboard systems to 5-6 different RF channels during production, one can get the theoretical probability for collisions even closer to 0.

6. CURRENT CONSUMPTION

Due to the high data rate given by ShockBurst the average current consumption of a nRF24xx -based design can be reduced considerably compared to existing low data rate 27MHz systems. By minimizing the active time of the RF front end (using ShockBurst) one minimizes the average current consumption.
For a mouse, utilizing nRF2402, the average current consumption when active and sending 2 packets for each mouse up date is:

$$I_{av} = \frac{2 \cdot (T_{stb2tx} + T_{oa}) \cdot I_{TX} + (T_{ud} - (2 \cdot (T_{stb2tx} + T_{oa})) \cdot I_{stby}}{T_{ud}}$$

$$I_{av} = \frac{2 \cdot (195\mu s + 88\mu s) \cdot 10mA + (10ms - (2 \cdot (195\mu s + 88\mu s)) \cdot 12\mu A}{10ms} = \underline{577\mu A}$$

Compared to the constant 10 mA of a low data rate system. When it comes to the total average current drawn by the mouse one has to take into account the active time each day etc. In the Nordic VLSI ASA white paper 3 axis mouse, some assumptions is presented and the following average current consumption and battery lifetime is calculated. Here it is found that the entire mouse will have an expected battery lifetime of 1.5 – 2 years from a 1000mAh cell.

In the receiver the current consumption of the nRF2401 will be 24 mA if it is kept on permanently running DuoCeiver. By implementing simple timing routines in the RX micro controller the RF front end can be shut down saving current here as well. Since PC's generally has ample power supply, this is more a question whether one has the needed timers free for this use.

7. CONCLUSION

Using the nRF24xx family of device's customers can make mouse/keyboard combo systems that:

1. Can operate in an environment with very good RF link integrity in the 2.4 GHz ISM band
2. Has an extremely low average current consumption in the peripherals (average RF current consumption only 0.5mA when active), extending battery lifetime.
3. Can utilize low-cost micro controllers while still offering 1 MBit/s data rates on the air, enabling outstanding RF performance, with likelihood of collision and blocking virtually eliminated.
4. Use low cost PCB antennas offering supreme range compared to existing 27MHz systems.
5. Very small physical outline, both RF layout and antenna.
6. Single-chip 2.4GHz solution which is optimized for high volume production.

8. LIABILITY DISCLAIMER

Nordic VLSI ASA reserves the right to make changes without further notice to the product to improve reliability, function or design. Nordic VLSI does not assume any liability arising out of the application or use of any product or circuits described herein.

9. LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Nordic VLSI ASA customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Nordic VLSI ASA for any damages resulting from such improper use or sale.

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YOUR NOTES

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