
# Frequently Asked Questions

## Version 1.00

NA-07-0108-0408-1.00

Chirp it.

## Document Information

| | |
|---|---|
| Document Title: | Nanotron Frequently Asked Questions |
| Document Version: | 1.00 |
| Published *(yyyy-mm-dd)*: | 2007-03-07 |
| Current Printing: | 2007-3-7, 3:21 pm |
| Document ID: | NA-07-0108-0408-1.00 |
| Document Status: | Released |

**Disclaimer**

Nanotron Technologies GmbH believes the information contained herein is correct and accurate at the time of release. Nanotron Technologies GmbH reserves the right to make changes without further notice to the product to improve reliability, function or design. Nanotron Technologies GmbH does not assume any liability or responsibility arising out of this product, as well as any application or circuits described herein, neither does it convey any license under its patent rights.

As far as possible, significant changes to product specifications and functionality will be provided in product specific Errata sheets, or in new versions of this document. Customers are encouraged to check the Nanotron website for the most recent updates on products.

**Trademarks**

nanoNET© is a registered trademark of Nanotron Technologies GmbH. All other trademarks, registered trademarks, and product names are the sole property of their respective owners.

## Table of Contents

1 What are the Advantages and Benefits of Chirp Signals? . . . . . . . . . . . . . . . . . . . . . . . . . . . 1
2 How do Nanotron systems achieve a higher range with lower transmission power? . . . . . . . 2
3 Nanotron's wireless technology is marketed as having "high robustness" and is called the "wireless wire". Why should the noise immunity of Nanotron's systems be better as compared to other systems? . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3
4 Chirp Signals are claimed to have extremely low human exposure. How is this possible? . . 4
5 In nanoLOC Chirp signaling is applied to measure the distance between transceivers. What is the advantage and what is the time accuracy between nodes? . . . . . . . . . . . . . . . . 5
6 What is meant by the multi access system "MDMA" developed by Nanotron and what are its advantages? . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 6
7 What happens when the transmitter and the receiver come very close together, such as 0.3 m, or when the receiver is very far away, such as 100 m, which is the so called "near-far problem"? . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 7
8 How do Chirp signals tolerate multi-path effects? . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 8
9 In the Fall of 2006 Nanotron launched the nanoLOC Chip. What is the difference between nanoLOC and nanoNET? . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 9
10 Nanotron has claimed that its systems are able to exploit transmission parameters (bandwidth, power and time) to an optimal extent. What does this mean? . . . . . . . . . . . . . 11
11 Is the system concept of Nanotron's wireless technology transferable also to other frequency bands such as 868 M Hz? . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 12
12 What is the estimate for further development of this technology in the next 3 to 10 years (with respect to range, data rate, receiver sensitivity, robustness in the crowded 2.4 GHz band, accuracy of distance measurement, and cost for each node)? . . . . . . . . . . 13
13 What happens if several independent CSS systems (i.e. of different suppliers) with diverse data rates are running in the same transmission area? . . . . . . . . . . . . . . . . . . . . . . . . . . . 14
14 Is coexistence with DSM technology of Spectrum possible? . . . . . . . . . . . . . . . . . . . . . . . . 15
15 Which applications are best suited for Nanotron's wireless technology? . . . . . . . . . . . . . . . 16

Intentionally Left Blank

## 1 What are the Advantages and Benefits of Chirp Signals?

Chirp signals are angle modulated[1] sweeping signals. They pass in a linear or nonlinear way the whole frequency bandwidth `B[Hz]` from one end to the other one by a sinusoidal waveform of constant amplitude within a certain time `T[s]`. If this sequence of frequencies is swept from the lowest to the highest frequency limit, we called it an *Upchirp*. In the opposite direction it is a *Downchirp*.

From a theoretical point of view, Chirp signals provide an astonishing number of advantages. They substantiate the following ideal features of a fundamental nature in communications engineering:

1 They have a quasi *ideal rectangular spectrum* to utilize the channel's capacity and to offer an optimal *lowest spectral power density* compared to all other existing transmission signals.

2 They are *programmable with respect to processing gain,* which means it is possible to achieve determinable distances in ranging while at the same time suppress adaptively disturbances and noise.

3 *All three main modulation modes* can be applied at the same time, each of which contributes specific physical parameters for optimal transmission properties, as follows:

- *FM (Frequency modulation)* contributes a robust transmission by a big *BT product*[2] and also guarantees an ideal spectrum shaping and processing gain.
- *AM (Amplitude modulation*) which is generated by the transformation out of the Chirp Signal, contributes the ideal spectrum as well as an ideal envelope function. This is the sinc function with the shortest duration possible at any given bandwidth, in order to use time effectively.
- *PM (Phase modulation*[3]*)* contributes the capability to transfer single bits in BPSK (Binary phase-shift keying), QPSK (Quadrature phase-shift keying) or a higher multiphase angle modulation mode. It is allows the transmission of bits by a combination of multi chirp modulation.

4 They *allow a high resolution on time axis* and are, therefore, best suited for ranging.

5 They enable systems that prove a *very short latency*[4] by asynchronously working correlative transmission systems.

6 Chirp Signals prove the ability to superpose these long signals to allow the data rate and bit energy to vary adaptively or to generate multi chirps in different combinations, which achieves other advantages.

7 They can be *processed in an analogue way* to realize low power solutions.

8 Chirp Spread Spectrum (CSS) Signals are *resistive against overloading* if chirps do not overlap.

9 Chirp Spread Spectrum (CSS) Signals are approximately *resistive against multi paths effects*.

10 Chirp Spread Spectrum (CSS) Signal systems *do not fail because of Doppler shifting*.

11 Chirp Spread Spectrum (CSS) Signals can be processed *asynchronously* and offer advantages in comparison to other systems which need to be synchronized. This ability lowers latency and improves coexistence ability.

1. Angle modulation is the umbrella term for frequency and phase modulated signals.
2. The bigger the product out of bandwidth and bit duration, the higher the robustness of an transmission system.
3. Chirp signalizing allows to apply phase modulation aside frequency modulation, the phase for the bits, frequency modulation to create the processing gain.
4. Latency represents the delay time between the inquiry of one transceiver and the answer of the asked transceiver.

## 2 How do Nanotron systems achieve a higher range with lower transmission power?

In contrast to what is commonly understood, the range of a transmission system is not a function of its power but of the energy of every single digital bit. For historical reasons, it has been commonly held position that the transmitter's power determines the distance to be bridged over. In the past when modulation modes had been of an analogue nature, the real time condition had to be kept. This meant that the duration of the signal was dependent on the frequency applied and, therefore, the time for each symbol could not be changed, if the simultaneity must be guaranteed. Therefore, the transmission power determined the energy and by this fact the range was given.

Today, however, symbols are represented by digital bits. Since energy results from the product of power `[W]` and time `[s]`, it is possible with relatively low power and long lasting pulses to create high bit energies `[Ws]` and to bridge over large distances between transmitter and receivers.

Moreover, from these considerations a quite different approach to wireless networks results. For physical and economical reasons, the bit energy *should be controlled in dependency with distance and noise ratios between the base station and the distinctive subscriber of a network* (see also *Question 10*).

## 3 Nanotron's wireless technology is marketed as having "high robustness" and is called the "wireless wire". Why should the noise immunity of Nanotron's systems be better as compared to other systems?

By frequency depending *group delay lines*, which do not have to work synchronously, Chirp signals can be transformed by analogue or digital means into *a sinc function.* The envelope of the carrier follows the $\sin(\pi \cdot B \cdot t)/(\pi \cdot B \cdot t)$ characteristics.

This represents a well known ideal pulse shape. It represents the shortest pulse possible at a given bandwidth with a very short duration $\delta_B[s]$, that of the quasi Dirac Pulse. It compresses the energy of the relatively long-lasting Chirp pulse with the duration $T[s]$ and the relatively low power $P_C[W]$ into the ideal shortest pulse possible with momentary power $P_S[W]$ (see *Figure 1*).

To easily understand the context and the deduction of the processing gain $G[dB]$, we apply the energy conservation law. The energy, and therefore the product out of power and time of both pulses, has to be equal, or:

$$P_C \cdot t = P_S \cdot \delta_B [Ws]$$

or hereof: $P_S = P_C \cdot T/\delta_B\ [s]$

which means the time spreading ratio $T/\delta_B$ to conduct to a respectively enlarged power $P_S$ with a processing gain $G$, due to the fact that $T \gg \delta_B[s]$.

According to the Nyquist – Shannon theorem, the average duration $\delta_B[s]$ of the Sinc Pulse is reciprocal to the bandwidth:

$$\delta_B = 1/B\ [s]$$

Inserted in the above equation: $P_S/P_C = B \cdot t\ [-]$

Or the processing gain becomes: $G = 10 \cdot \log\ (P_S/P_C) = 10 \cdot \log\ (T \cdot B)\ [dB]$

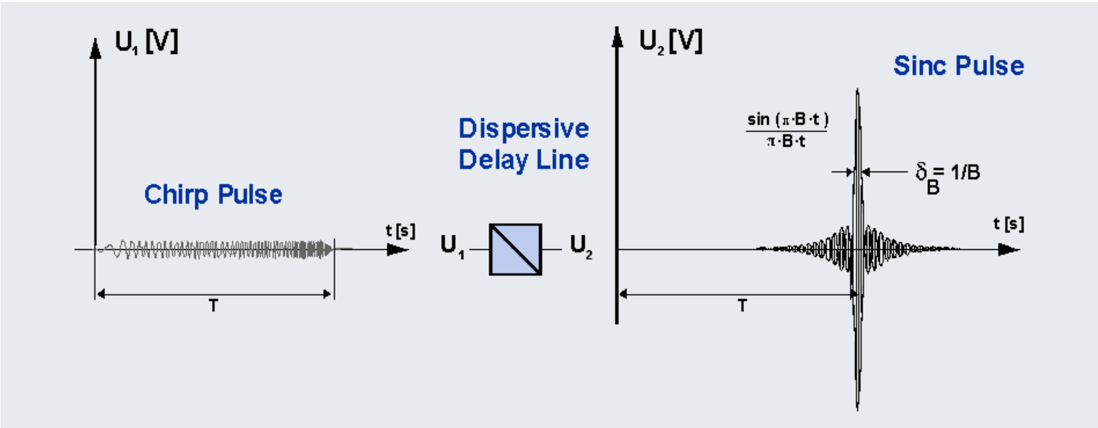


*Figure 1: The transformation of the Chirp Pulse into the Sinc Pulse by a group delay line filter*

*The longer the duration* $T[s]$ *of the Chirp pulse (Time Spreading) and the bigger the applied bandwidth* $B\ [Hz]$ *(Frequency Spreading), the higher the processing gain***.** That is, the super elevation of the compressed Sinc Pulse in comparison to the uncorrelated signals means that there is a capability to suppress distortions or noise adaptively. Thus transmission systems with an adaptive processing gain can be managed by a verifiably ideal methodology to disable noise of any kind and / or to adjust the Bit Energy to the distance to be achieved.

## 4 Chirp Signals are claimed to have extremely low human exposure. How is this possible?

Human exposure, commonly called “electro-smog”, is measured in `W/kg`, according to American FCC regulations. Others argue that a small power spectral density is acceptable for human exposure. Chirp signals comply with both conditions.

At certain distances, time spreading allows for a considerable reduction of the transmission power. Significantly, the power spectral density is extremely low due to the ideal rectangular spectrum, in comparison with other transmission signals (see *Figure 2* below).

*Chirp Signals can be modulated by their bit duration; therefore, they can achieve with relatively low power long distances in comparison with other transmission systems.*

For example, with a transmission power of only `1 µW` and `1 Mbit/s`, which is 1/10000 times the power of Bluetooth, Chirp signals can be transmitted `15 m` indoors, and the power spectral density is even much less. A cellular telephone in Europe, by comparison, applies power a million-fold, that is `1 W`.

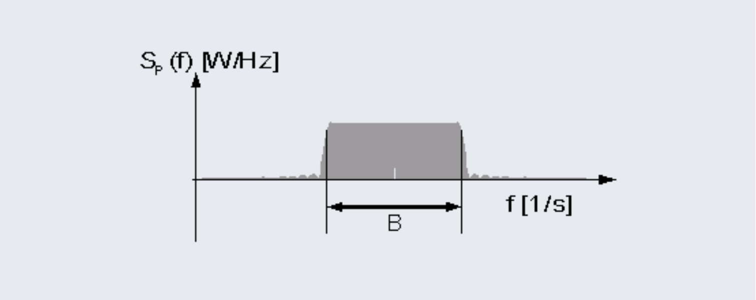


*Figure 2: The nearly ideal rectangular spectrum of the chirp and the sinc Pulse*

## 5 In nanoLOC Chirp signaling is applied to measure the distance between transceivers. What is the advantage and what is the time accuracy between nodes?

One of the advantages of Chirp signaling is its ability to offer at a given bandwidth the highest resolution on the time axis by the transformed sinc pulse. This is why Chirp signaling is optimally suited if we use the run time measurement of electromagnetic waves to determine the distance between two transceivers via the known speed of light. In radar technology, this methodology with Chirp signals has been used in a similar way since 1962.

The duration of the sinc signal at a bandwidth of 64 MHz is: $1/(64 \bullet 10^6) = 15.6$ ns

The rise time of this pulse is about: $0.3 / (64 \bullet 10^6)$

These are 4.7 ns.

Let us suppose that the Signal to Noise ratio would be 20 dB; referred to voltage this means a ratio of 10. If we divide 4.7 ns by 10 we receive 0.5 ns accuracy. This results in a speed of $3 \bullet 3^8$[m/s] into a resolution of 0.15 m.

If we consider noise, reflections, and other disturbances, we can assume an accuracy of less than 0.5 m at a distance of 50 m.

At strong reflections or even without line of sight, however, it is unavoidable that mismeasurements may occur. In this case it is recommended that multi-path measurements with several transceivers be applied.

## 6 What is meant by the multi access system "MDMA" developed by Nanotron and what are its advantages?

MDMA (Multi Dimensional Multiple Access) implies a the simultaneous implementation of a flexible time multiplex system, an adaptive data rate, and a bit energy variation system. For the latter, it is a system that can be controlled in several dimensions to optimize the exploitation of the channel's capacity and the energy volume of a network.

The frequency modulated Chirp signals can be sequentially superposed and, despite this interference, can be separated on the time axis again by transformation (see *Question 3*). To that purpose the single Chirp sequences must be staggered time-wise.

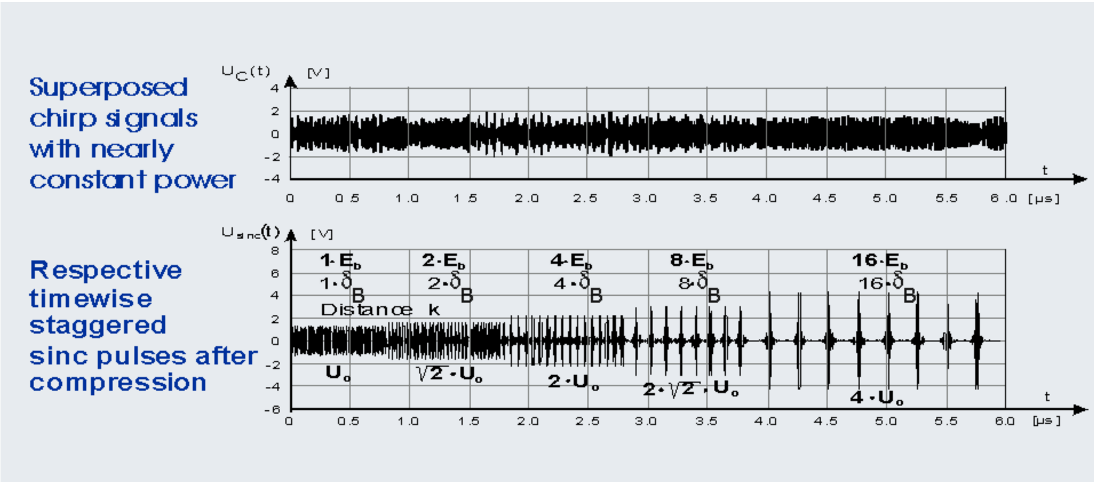


*Figure 3: Time-wise staggered and superimposed Chirp Signals with adjusted power result at the receivers end into Sinc Pulses with increased bit energy at reduced data rate*

This staggering requires distances of integer multiples of the minimum duration $\delta = 1/B[s]$, with a consequence of $1 \cdot \delta_B$, $2 \cdot \delta_B$, $3 \cdot \delta_B$, ... $n \cdot \delta_B$ to avoid distortions by superposing of the pre and post pulsations of the sinc functions after compression. By this methodology it is possible to control the pulse sequences in such a way as to get different data rates by different bit energies per pulse sequence at an always constant transmission power (MDMA).

The result is that while the transmission power is constant it is possible to generate time-wise staggered superposed chirps to receive at the receivers bits with different bit energies (see *Figure 3*).

## 7 What happens when the transmitter and the receiver come very close together, such as 0.3 m, or when the receiver is very far away, such as 100 m, which is the so called “near-far problem”?

These deficiencies are caused by over-steering of the input amplifiers. Here, however, Chirp signals are robust against any over-steering similar to a FM receiver, where even an FM signal can be limited in amplitude. Nevertheless, FM signals are immune against non-linear distortions.

For the receiver circuitry this has many benefits, especially for gain control and for the prevention of the incompatibility of many systems such as CDMA to avoid failures caused by the “near - far problem”. Even if some subscribers are very far away, a too large an input power for the near subscriber would not cause malfunctions. There is, therefore, no minimum distance specification as with other systems.

# 8 How do Chirp signals tolerate multi-path effects?

Chirp Spread Spectrum (CSS) Signals[5] are to a certain extent immune against reflections. Chirp signals that are not superposed are pulses of relative long duration with large time spreading and which are transformed by frequency group delay filters into frequency spread sinc-pulses of a very short duration (see *Figure 1*).

If at the receiver antenna, direct line-of-sight and reflected (non-line-of-sight) signals are superposed, than we can assume `1000 ns` lasting Chirps; for example, the reflected signals in closed rooms arrive within `10` to `200 ns`. However, the compressed signal has a duration of about `16 ns` at a bandwidth of `64 MHz`. Its duration, consequently, is only `1.6%` of the repetition time and can be detected independent from the multipath signals which arrive much later.

If we consider that, theoretically, a reflected signal can occur in the subsequent period, than the runtime must take more than `1000 ns`; this is correspondingly a distance of more than `300 m`. But the indirect signal is now attenuated in comparison to the direct line of sight signal and the level depending detection hurdle keeps the reflected signal within the noise level.

5. These are chirp signals which do not overlap on the time axis

## 9 In the Fall of 2006 Nanotron launched the nanoLOC Chip. What is the difference between nanoLOC and nanoNET?

Both chips are CSS systems and offer all advantages of chirp technology as described in *Question 1*. Both utilize the highly effective Chirp spectrum, and both offer the processing gain and the high flexibility of a time multiplex system.

The essential difference between *nanoNET* and *nanoLOC* is the group delay filter which is implemented in the *nanoLOC* Chip. *While nanoNET requires an external SAW filter, the nanoLOC offers a one chip solution with an internal digital structure.* This provides a cheaper solution for the customer.

Moreover, this digital correlation filter is programmable and can be employed for a chip duration of 0.5; 1.0; 2.0; and 4.0 µs. This means that by four logarithmic graduated steps by software or by automatic control the bit energy can be parameterized. By stepping the bit energy by a factor of two, the gain in range results by the factor of $\sqrt{2}$ for each step.

This variability of the Chirp length creates an additional reserve in capacity with respect to the usage of energy and time of the network. Because single participants in a network have (typically) different distances to the base station, an economically operating network should apply shorter Chirp signals at shorter distances, since less energy is necessary than for longer distances.

The energy emitted from the antenna declines in spherical radiation by the square with the radius. Therefore, the double distance needs the quadrupled energy or power; or in the opposite direction: for the half range a quarter of energy. Since, however, at the same transmission power the duration of the signals determines their energy it is possible to transmit four times faster for half of the range.

These simple considerations have a big impact on transmission technologies. It implies that a network can be organized with a much higher sum data rate than in the past. Instead of applying the same data rate for all subscribers scaled to the most dislodged participant, it is more economical to speed up the data rate by a factor of four for half of the distance. This results, for example, in a logarithmic rising speed at reduced distance to the base station. This procedure saves time and offers the ability to provide either more participants or to supply higher total data rates.

Above all, the *nanoLOC Chip* offers not only an effective bandwidth of 64 MHz like the *nanoNET* chip, but also the choice to work with three different channels alternatively. These have an effective bandwidth of 22 MHz each (see *Figure 4* below). Therefore, it is possible to reduce coexistence problems in non-licensed bands like in the ISM bands which have to accommodate more and more channels.

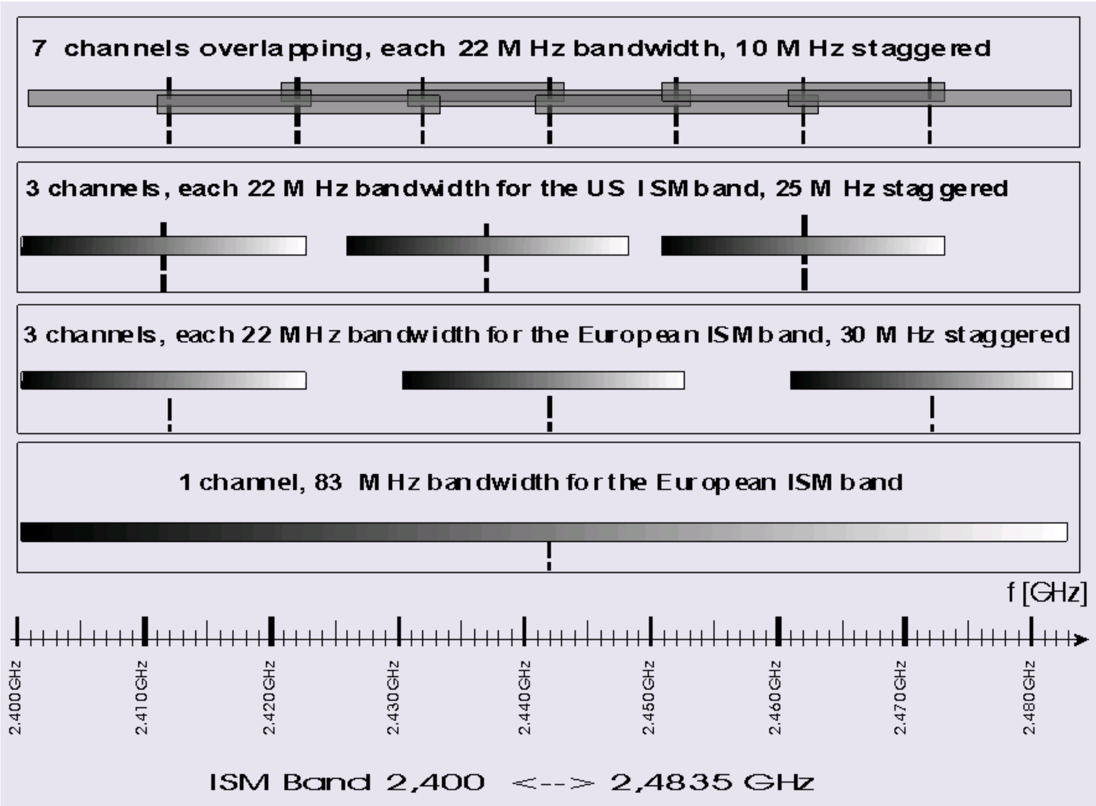


*Figure 4: General survey over the selectable bands and their positioning in the ISM band in Europe and USA for the nanoLOC chip*

Moreover, the *nanoLOC* chip can operate with 7 overlapping channels with a bandwidth of `22 MHz`, but in a frequency raster of only `10 MHz`. Chirps allow such overlapping frequency operation due to the fact that time-wise staggered signals create an offset on the time axis for the amplitude modulated compressed signals and these can be separated, for example, by synchronized time windows.

Nanotron, therefore, continues its careful consideration of how to intelligently use modern transmission technology to explore how rare resources in crowded bands can be used in an economic and robust way.

## 10 Nanotron has claimed that its systems are able to exploit transmission parameters (bandwidth, power and time) to an optimal extent. What does this mean?

The wireless technologies developed by Nanotron are able to operate systems, in comparison to conventional technologies, in a consistent way. This means that these technologies

- Can exploit the frequency domain steadily and perfectly by the ideal form factor of the Chirp spectrum.
- Allow a variable staggered data rate specific to each participant based on its distance and noise level. This is done in order to use the channel capacity in such a way that the limited time for one up and / or down link is organized in a time multiplex operation system in a flexible and optimal economic way.
- Offer asynchronous operation modes.
- Are immune versus the Doppler effect, even at manifold acoustic velocity.

From a theoretical point of view, as compared to traditional systems with invariant data rates or with power management or inadequate usage of the spectrum, these advantages prevail up to now in a unique manner and are the fundamental to the superior parameters of Nanotron chips and Chirp technology (see also the answer to *Question 1*).

## 11 Is the system concept of Nanotron's wireless technology transferable also to other frequency bands such as 868 M Hz?

Yes, of course. Technically, this philosophy can be applied for all frequency bands including 868 MHz. However, it should be considered advantageous when a sufficiently high bandwidth is available, for example minimum `10 MHz`. Best suited are higher frequencies such as `2.4` or `5.6 GHz` where enough bandwidth is available for a big BT Product.

Not only can license-free bands benefit from Nanotron's technology but also licensed bands. For example, Nanotron's technology is a perfect solution for wireless local loop applications to solve the "last mile problem". The technical feasibility has been proven by the existing chips.

## 12 What is the estimate for further development of this technology in the next 3 to 10 years (with respect to range, data rate, receiver sensitivity, robustness in the crowded 2.4 GHz band, accuracy of distance measurement, and cost for each node)?

The current high range of this technology will be more than doubled by the adaptive bit duration. Similarly, the sum data rate of a network and the sensitivity will increase by adaptively increasing processing gain.

The robustness with rising transmission traffic is limited. Since our systems can improve immunity against disturbances, depending on the location of the receiver, by varying of the bit energy individually, our robustness will prevail in comparison to other systems unless others apply our philosophy. The accuracy of ranging of our system is today more than twice as high compared to other LAN systems and for physical reason it cannot be better than today.

The cost will shrink over the years by cost reduction of the advanced chip technology and with rising quantities. If the purchased quantities will exceed one million a year, the ex factory price will drop beneath 4 Euro per chip unit and products with additional components, battery, and housing will decline down to less than 10 Euros manufacturing cost at quantities of more than 100 k units a year.

## 13 What happens if several independent CSS systems (i.e. of different suppliers) with diverse data rates are running in the same transmission area?

Unless the systems cannot be separated on the time axis by intelligent synchronizing operation modes, it is possible to escape by usage of different channels on the frequency domain or even to use a combination out of both. On the other hand, there are physical limits for parallel operation on the time and/or frequency domain (See also *Question 9*).

## 14 Is coexistence with DSM technology of Spectrum possible?

DSM is, according to our information, a small band Direct Spread Spectrum technology. The data rate is 15.6 kbps and the channel raster is 1 MHz. By a search criterion, a free channel is scanned and this free channel is then continuously used. The transmitter output power amounts to a considerable 20 mW. Despite this and due to the small band system, there is no probability of collision with this kind of system as our broad band system will not collide with small band systems and vice versa, as tests have proven.

Similar results have been shown from test measurements with Bluetooth. Bluetooth receivers do not show significant disturbances if they are moved more than 25 cm from *nanoNET* transmitters. Similar results can be shown if a Bluetooth transmitter is more than 38 cm away from a *nanoNET* transceiver (Both with transmitter power of 10 mW). With a DSM system, the results would be the same.

## 15 Which applications are best suited for Nanotron's wireless technology?

Nanotron's wireless technology can be applied in almost all possible wireless applications. Why? The different preferences as listed in *Question 1* open a complex bargain of opportunities for more than 100 applications possible. Because these technologies are based on clear general physical principles which are valid for any wireless transmission, there is no restriction.

The following is a list categories of applications with many different implementations of these categories.:

| Category | Implementation |
|---|---|
| Air-conditioning | Wireless control of heating and ventilation |
| Audio and video transmission | Wireless indoor and outdoor video and audio data transfer with or without compression |
| Automotive engineering | Wireless control of vehicles, motors, kinematics data, etc. |
| Medical appliances | Wireless metering on the human body, i.e. pulse, temperature, aeration, movements, EEG, ECG, different infections and much more. |
| Meter reading | Water flow meter, heat meter, electrical energy, etc. |
| Private Communication systems | Audio and video transmission, door bells, baby phone, data networking, etc. |
| Quality control | Layer thickness, velocity, length, pH-value, etc. |
| RFID Systems | Active and passive RFID, persons identification, logistics, containers, automatic entrance surveillance, tracking etc. |
| Security | Buildings, automobiles, caravan, theft control, video surveillance equipment, etc. |
| Sensor and Actor systems | Home appliances, safety control, assembly, production lines, heating equipment, etc. |
| Tele-control | Doors, window blinds, TV sets, garage doors, motor models, flying models, toys, etc. |
| Telephone | Cellular telephone, cordless telephone, Wireless Local Loop, etc. |
| Traffic Control | Toll systems, traffic control, theft control, etc. |
| Warning systems | Fire detectors, rain sensors, humidity, earthquake, radioactivity, strain gauges on bridgework, etc. |

# Revision History

| Version | Date | Description/Changes |
|---|---|---|
| 1.00 | 2007-03-07 | Initial Version. |

# About Nanotron Technologies GmbH

Nanotron Technologies GmbH develops world-class wireless products for demanding applications based on its patented Chirp transmission system - an innovation that guarantees high robustness, optimal use of the available bandwidth, and low energy consumption. Since the beginning of 2005, Nanotron's Chirp technology has been a part of the IEEE 802.15.4a draft standard for wireless PANs which require extremely robust communication and low power consumption.

ICs and RF modules include the nanoNET TRX, the nanoLOC TRX, and ready-to-use or custom wireless solutions. These include, but are not limited to, industrial monitoring and control applications, medical applications (Active RFID), security applications, and Real Time Location Systems (RTLS). nanoNET is certified in Europe, United States, and Japan and supplied to customers worldwide.

Headquartered in Berlin, Germany, Nanotron Technologies GmbH was founded in 1991 and is an active member of IEEE and the ZigBee alliance.

### Further Information

For more information about this product and other products from Nanotron Technologies, contact a sales representative at the following address:

Nanotron Technologies GmbH
Alt-Moabit 60
10555 Berlin, Germany
Phone: +49 30 399 954 - 0
Fax: +49 30 399 954 - 188
Email: sales@nanotron.com
Internet: www.nanotron.com