Phonak Insight.

Roger™ - The wireless technology standard

This Insight describes the details of, and the reasoning behind, the Roger technology.

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Key highlights

- Roger allows for low-delay and reliable broadband audio broadcast towards miniature low-power receivers, that can be connected or installed to hearing instruments or cochlear implant sound processors, as well as towards soundfield loudspeakers.

- Sophisticated adaptive algorithms at different levels in the Roger architecture give Roger a performance level which was not previously considered physically possible.

- At the same time, automatic features and simple pairing concepts make management and use of Roger systems very easy.

Reasons for the standard

- The choice of transmission technology in the development of a wireless standard has an impact on several important features of the final platforms and products. It was the following list of questions that steered Phonak to develop a wireless technology standard from scratch and not to pick something of the shelf.

- Is it possible to go significantly beyond the performance of the best technology available today, in terms of speech recognition in noise, over distance and in reverberation?
- Is it possible to reduce set-up complexity, management and usage of wireless systems for listeners with hearing loss?
- Is it possible to develop a technology standard that does not force schools to write off investments of the past but lets them transition gradually to the standard?
- Is it possible to develop a standard that offers full and seamless compatibility with other brands of hearing aids, with all brands of cochlear implants, with solutions for listeners with normal hearing, and with soundfield systems?
- Is it possible to enlarge the audio bandwidth and keep the end-to-end audio delay of the standard within acceptable limits?
- Is it possible to lower the noise floor and to enhance the system's dynamic range in the audio domain?
- Is it possible to altogether avoid dead spots in a room where the wireless microphone does not reach a receiver?

- Is it possible for the standard to avoid interference from similar nearby systems or from any other appliances such as WiFi (2.4 GHz) networks, tube lighting (low frequency inductive interferences), Bluetooth devices (2.4 GHz), different generations of GSM networks (800 to 900 MHz) or from sunlight (as often is the case with infrared systems)?
- Is it possible to create a standard that can both send and receive?
- Is it possible to send control data in parallel to the audio stream?
- Is it possible to create one technology standard for the entire world, which allows users the freedom to travel and use their systems everywhere, without having to change channels, and which can be serviced everywhere?

For existing technologies we could only give positive answers to just a few of these questions, but no existing technologies could provide satisfying answers to all of them, especially not to the first four questions of this long list. The most important question – Can we further improve speech understanding in noise? – definitely required a new approach. This inspired Phonak to develop a standard, with the ambition of making zero compromises. It took many years and a large group of audiologists and engineers working in micro-electronics, software, acoustics, radio frequency, protocols and mechanical design to develop the standard: Roger.

Digital adaptive wireless at 2.4GHz

Roger is an adaptive digital wireless transmission technology running on the 2.4 GHz band. Audio signals are digitized and packaged in very short (160 µs) digital bursts of codes (packets) and broadcast several times, each at different channels between 2.4000 and 2.4835 GHz. Frequency hopping between channels, in combination with repeated broadcast, avoids interference issues. End-to-end audio delay is well below 25 ms, and Roger systems are tap-proof.

The frequency hopping Roger employs is adaptive, which means only free channels are used. Roger receivers regularly talk back to the transmitting wireless microphones, informing the system about which channels are steadily occupied (by any other nearby system operating at 2.4 GHz, like a WiFi network) and which channels are free. The Roger wireless microphone then automatically 'hops' around these occupied channels. The Roger wireless microphones can also sense the presence of a WiFi network, and respond to this accordingly.

Simulation calculations for a worst-case scenario with one Roger system in stacked blocks of 8 x 8 x 2 meters revealed that no self- interference will occur. In other words, there is no limit to the number of Roger systems that can be used in one building. If, despite all efforts, a Roger audio packet is not received correctly, intelligent packet loss concealment algorithms on the receiver side 'fill in the blanks' to ensure sound quality and listening comfort.

In comparison, with Bluetooth the repetition of packet broadcast is only on demand of the receiver, or even without repetition with the SCO protocol (used in the first headsets). If acknowledgement of a packet's reception does not arrive at the Bluetooth transmitter, the packet is broadcast again. This means that Bluetooth receivers are quasi-continuously transmitting back to the transmitter, which significantly increases power consumption at the Bluetooth receiver. With Bluetooth the maximum number of receivers is also limited to three, which means that even just two listeners with binaural ear-level Bluetooth receivers cannot listen to one and the same Bluetooth stream, let alone larger groups.

In the Bluetooth headset protocol the audio delay is still acceptable (10 to 15 ms), but the audio bandwidth is often limited (up to 4 kHz), unless one uses the 'wideband speech' feature of the hands-free profile version 1.6, which can go up to 7 kHz. In the Bluetooth Audio Streaming protocol, A2DP, the bandwidth increases to 20 kHz, but the audio delay of well over 100 ms prevents it from being suitable for live face-to-face communication. Only with special Bluetooth chips on both ends can this delay be reduced, to around 40 ms. Additionally, the A2DP Bluetooth protocol allows for just one receiver, and the power consumption at that receiver is even higher than in the head-set protocol.

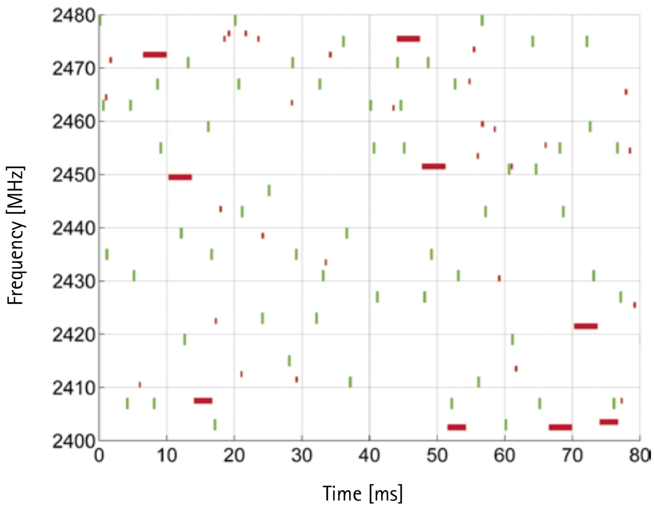

Figure 1
By hopping frequencies and repeated broadcast of audio packets, mutual interference can be minimized.

Roger systems broadcast audio packets at different channels within the 2.4 GHz band (between 2.4000 and 2.4385 GHz), which means different carrier wavelengths are selected. A receiver can receive such packets directly via line of sight, but also through a different path when the electromagnetic radio waves are reflected from the walls, the floor or the ceiling. The different lengths of the different signal paths can enhance or reduce the electromagnetic field's strength at the position of the receiving antenna, depending on the phase and amplitude differences of the different waves. This interference behavior is dependent on the wavelength. Randomly selecting the different channels at which an audio packet is broad-cast somewhat reduces the likelihood that all waves will cancel each other out at the receiving antenna by multipath fading if more than one receiving antenna is used. In other words, if one of the antennas is suffering from multipath fading (receiving signals that cancel each other), there is a high probability that the other antenna will not suffer from multipath fading.

In summary, the mitigation of interference is achieved by time diversity (broadcasting audio packets several times after one another), by frequency diversity (broadcasting audio packets at different carrier wavelengths, enhancing the chance that if one packet is canceled at arrival, another packet is not canceled), and, in the case of Roger SoundField, also by space diversity (employment of two receiving antennas separated in space, optimizing reception). (See Figure 2).

Roger offers a full audio frequency bandwidth, from 200 Hz to 7300 Hz. The system's internal signal-to-noise ratio is around 55 dB. With Roger no line of sight is required as it is with many infrared systems, and interference from sunlight or other strong light sources cannot occur.

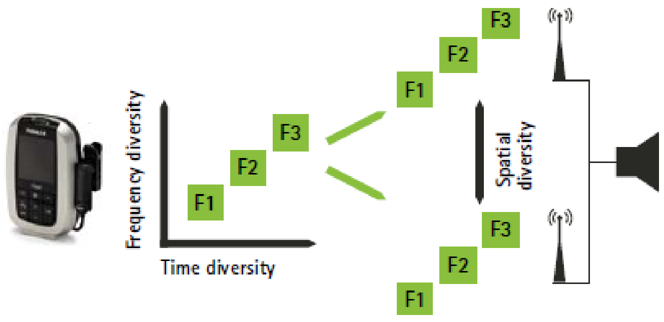

Figure 2
Mitigation of interference by time, frequency and space diversity.

With Roger it is not only possible to transmit an audio signal, but also to transmit and receive control data, for instance such as is required when setting up and/or maintaining a MultiTalker Network and to continuously monitor various network components to ensure proper operation. Electromagnetic waves at 2.4 GHz have a wavelength of about 12.5 cm. This allows for the design of new, small wireless micro-phones with short, built-in antennas. At 800 MHz the wavelength is 37.5 cm and at 200 MHz (in the traditional FM frequency range) the wavelength is 1.5 m, which requires for instance the external microphone cable to be the radio antenna.

The Roger chip

For miniaturized ear-level receivers Phonak developed a Roger chip (see Figure 3), as no existing integrated circuit could fulfill the demands. The Roger chip contains 6.8 million transistors (a Pentium Pro Processor by comparison has 5.5 million). Analog and digital blocks are situated next to RAM, ROM, EEPROM and Flash memory blocks on a miniscule chip.

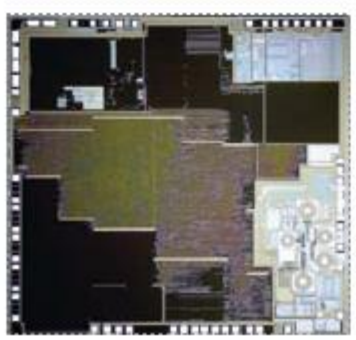

Figure 3
The Roger microchip.

Performance in noise

Roger wireless microphones continually estimate the ambient noise level with the highest precision. These measurements in turn control the gain of Roger receivers. In parallel with the broadband audio signal, control bits are sent to Roger receivers to adaptively adjust the gain to suit the acoustical environment in which the Roger system is being used. The range of adaptation is larger than in Dynamic FM. This advanced dynamic behavior has led to significant improvements in speech recognition in noise, especially at higher noise levels of up to 80 dB(A) (noise levels that are quite common in daily life, especially in public places and in the workplace). Related study results – by professor Linda Thibodeau, PhD, and Dr. Jace Wolfe , PhD – are summarized in two Phonak Field Study News editions: 'Roger for Hearing Instruments' and 'Roger for Cochlear Implants'. Figure 4 shows the main findings of Dr. Thibodeau's study.

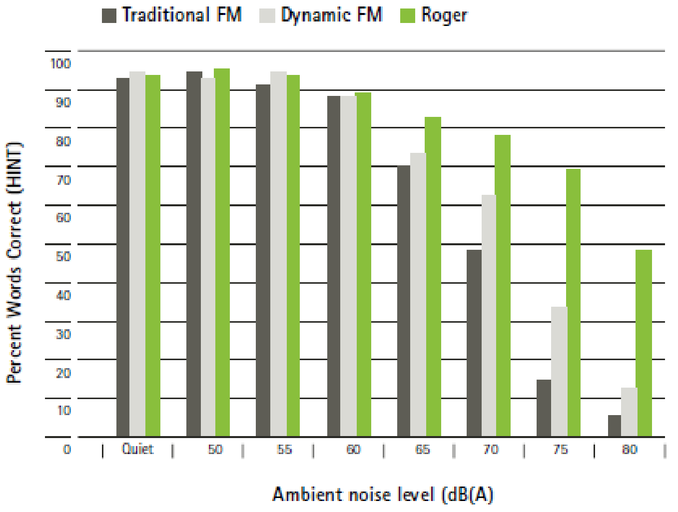

Figure 4
HINT percent correct scores for total words correct as a function of noise level for traditional FM, Dynamic FM and Roger. Distance between loudspeaker generating speech and listener was 5.5 m. N=11. At the 80 dB(A) noise level 9 participants scored <10% for traditional FM, 6 scored <10% for Dynamic FM, and only 1 scored <10% for Roger.

Next to this innovative dynamic behavior, Roger also uses a new advanced algorithm for the beam forming of the wireless microphone. This beam former is capable of suppressing noise from the left and right sides simultaneously, without introducing inacceptable distortion or overall frequency response changes. For wireless microphones in high-noise surroundings, this beam former significantly improves the signal-to-noise ratio at the source, enhancing intelligibility for the listener.

Ease of management and use of Roger

One of the barriers to the uptake of wireless technology has been its complexity or perceived complexity. The management of wireless solutions in the school environment – with special fitting software required to allocate and program microphone and receiver channels – has also been a burden. With Roger, frequency planning and programming is no longer required. Network building is quick, simple and very user-friendly. The pairing of a Roger inspiro with a Roger SoundField loudspeaker is equally simple; just one press of a button, and once paired the two components stay paired (including after switch off).

Dual transmission mode

The inspiro and DynaMic wireless school microphones are capable of transmitting both Dynamic FM radio waves to Dynamic FM receivers, and Roger waves to Roger receivers and Roger SoundField. This dual transmission mode allows schools to gradually phase out Dynamic FM receivers and phase in Roger receivers. (Note: the inspiro in question must be inspiro Premium (firmware version 3.0 or later). The same firmware versions are required for the DynaMic.)

A firmware upgrade to 4.0 will give these wireless microphones dual transmission mode capabilities. The same is true for the inspiro AudioHub.

Power consumption

Power consumption is well within reasonable limits both for Roger wireless microphones and for Roger receivers. A fully charged school Roger wireless microphone battery will last 7 to 8 hours when operating in dual transmission mode; easily long enough to cover a full school day.
Roger miniaturized ear-level receivers in active mode consume around 3 mA. This can normally be supplied by a hearing aid battery without problems.

Freedom to travel

As 2.4 GHz is a freely accessible band worldwide (a so-called ISM band: Industry, Science and Medical), no license is necessary. This means users of Roger systems can enjoy the freedom to travel and use their systems around the world. Servicing Roger systems while traveling is also simplified as the standard is the same in every country.