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Acoustic Wireless Control - connecting smart phones to hearing instruments

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Abstract

With the widespread use of smart phones, the benefit to transmit data directly from smart phones to hearing aids for control purposes has arisen. The touchControl App and binax hearing instruments enable this functionality for all binax hearing instruments from virtually all smart phones without the need for an intermediate relay, or wireless antennas in the hearing instrument. This paper describes the digital transmission system – Acoustic Wireless Control, which constitutes a direct link from a smart phone to the hearing instruments.

Control of hearing instruments by smart phones

Due to individual situation-dependent amplification needs [1], the adjustment of the hearing instrument loudness, frequency shaping, or selection of preference settings is an important user feature. User satisfaction with ease of basic volume control adjustments is however a problem [2] driven also by the fact that a large share of miniBTE instruments do not feature an on-board volume control. As a result, the variety of remote controls from manufactures increases, comprising discreet remotes with reduced functionality and larger remote controls which include a display and more control abilities.

However, not all hearing impaired users, who require manual adjustments of their hearing instrument settings, are willing or able to carry around an additional accessory. Smart phones are ideal candidates to be used as a remote control to avoid extra accessories. Also, they come with comfortable user interfaces such as touch screens and unified operating systems. The use of standard wireless system such as Bluetooth for remote control from smart phones is evident and feasible. However, drawbacks include high power consumption when a Bluetooth receiver is used in the hearing instrument or the need for an additional body-worn accessory which includes Bluetooth. Additionally, certain instrument types without a wireless interface are unable to support remote control functionality.

An alternative approach is to use a communication channel well suited for all hearing aids: data transmission by acoustic signals. Picking up sound via the microphones is a central function of a hearing aid that is already available. The additional resources required by the hearing aid in terms of size and power consumption are minimal. This makes this type of link perfectly suited for hearing aids - from super power devices to even the smallest CIC.

The challenge of acoustic data transmission

While the idea of using acoustic transmission to control a hearing instrument from a smart phone is not new, previous attempts suffered from poor usability and were conspicuous. A robust, practical and inconspicuous acoustic data transmission system from a smart phone to hearing instruments is difficult to achieve, for several reasons:

- The propagation of the signal in a room with walls and objects creates different sound paths, which interfere with each other and may lead to distortions.
- The signal is superimposed by environmental noise, which may mask the signal.
- The signal is damped in amplitude due to the distance of the hand held device to the ear. Also the loudspeaker of the smart phone may not face directly to the hearing aids in a typical situation causing additional loss of amplitude. (e.g. the loudspeaker is on the back side of the smart phone facing downwards)
- The control signal should be discreet, ideally not audible, in order to not alert others to the fact that the user is wearing hearing instruments.

Acoustic Wireless Control

An existing solution for acoustic control uses very audible dual tone multi-frequency (DTMF) signals in the range of 700-1600Hz. However, those are often superimposed on environmental sounds and thus the control frequently fails to operate in loud environments, where a change of instrument settings is often desired. In quiet environments, the phone must be brought in close proximity to the hearing instrument. A higher robustness against environmental effects can be achieved by designing the system in a frequency range where minimal ambient noise is present, i.e. close to ultrasound.

The principle of ultrasonic data transmission was introduced by Siemens in 1987 with the Telos remote control. With the prevalence of today's smart phones, this approach is revisited by the Acoustic Wireless Control with a digital design in the 15 kHz frequency region. The masking effect of surrounding sound sources like speech or noises is minimized since their energy in this frequency range is marginal.

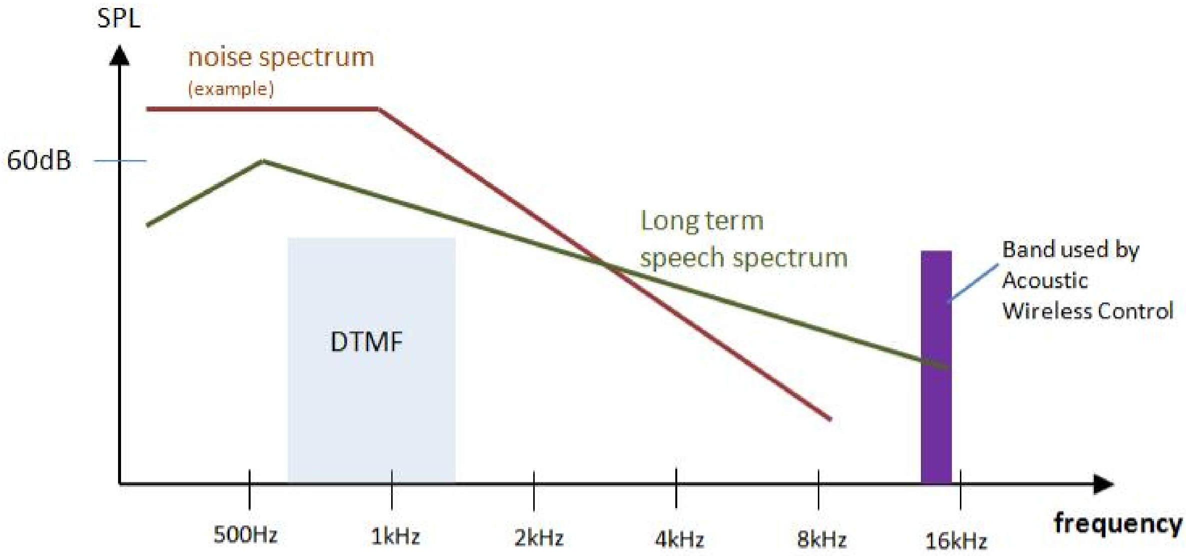

Figure 1: Frequency band used by the Acoustic Wireless Control compared to a speech spectrum and a noise spectrum.

Additionally, the audibility of the control signal for others is minimized as the hearing threshold rises steeply at 15 kHz. Moreover, this frequency range often becomes completely inaudible due to the natural aging effects of the ear.

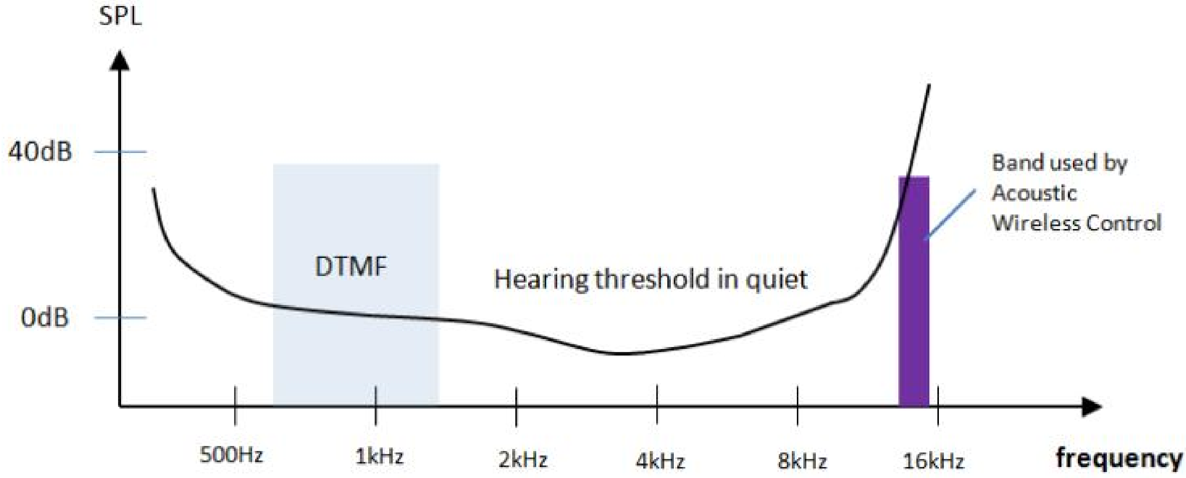

Figure 2: Frequency band used by the Acoustic Wireless Control compared to a hearing threshold in quiet.

The overall transceiver system is outlined in Figure 3. The Acoustic Wireless Control in the hearing instrument platform binax [3] is able to process the frequency range above 12 kHz separately from the audio signal processing band to extract the dedicated control codes. And in order to enable any iOS or Android smart phone to transmit these control codes, users simply need to download the corresponding touchControl App.

To avoid any conflicts between different touchControl App users, each transmitted data code is combined with a unique address. Before using the touchControl App, a pairing process with a specific smart phone determines this unique address used for communication. By doing so, any risk of the instrument being remotely controlled by another user's smart phone is excluded.

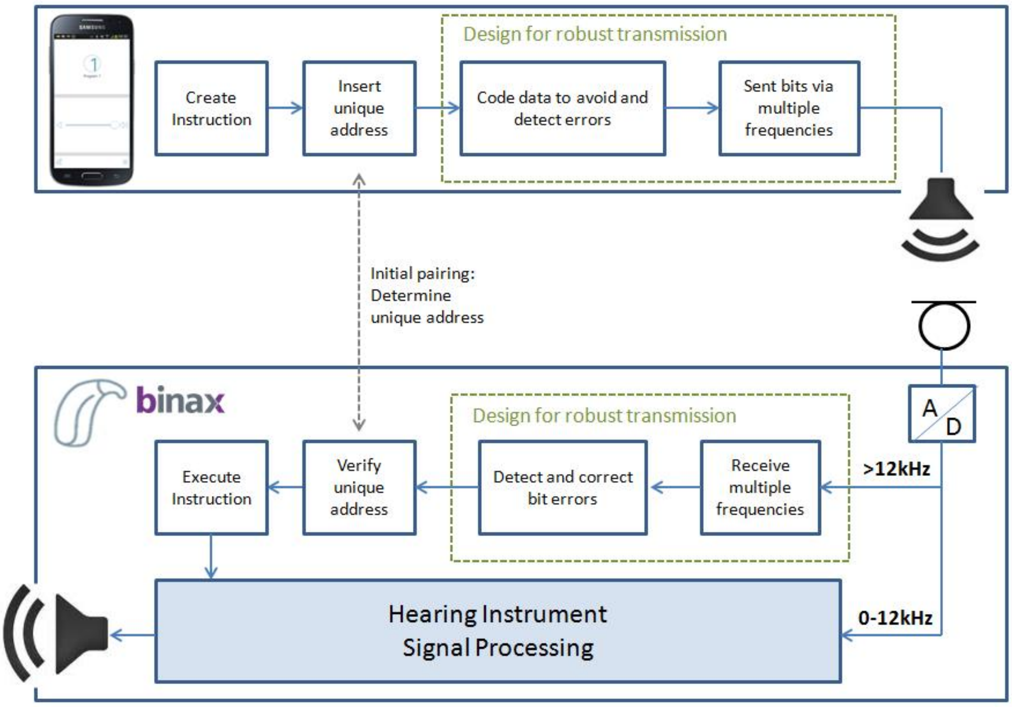

Figure 3: Overview of the Acoustic Wireless Control transmission system.

Design for robust transmission

Design measures to reach a high robustness against environmental effects and false alarms include adding redundancy to the transmission symbols to correct or detect errors and transmitting bits on various carrier frequencies.

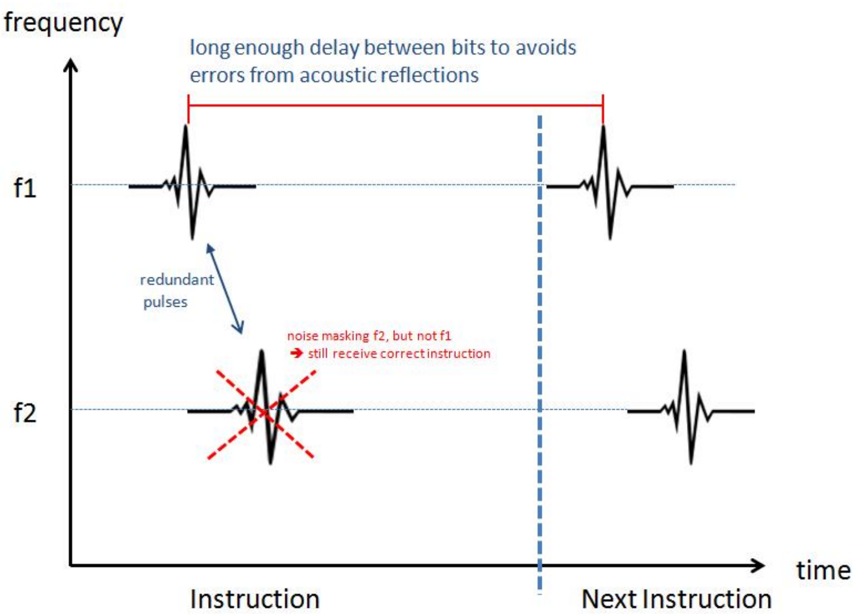

Figure 4: Principle of the Acoustic Wireless Control system using various carrier frequencies and redundancy spread over different frequencies. This helps to transmit robustly in low SNRs and in rever-

berant environments. In this example, two sequential pulses carrying digital information are sent on frequency f1 and f2. While the first pulse on f2 is masked by environmental noise, the digital information can still be recovered from the pulse of f1.

- The smallest piece of information is a single-frequency pulse followed by a fixed delay to minimize interference by acoustic reflections. This avoids errors from reverberations, i.e. acoustic reflections, leading to one pulse arriving at the receiver at the same time the next pulse is expected.
- The information is duplicated and transmitted on different carrier frequencies. If a single frequency is especially affected by noise, the information can still be reconstructed in the receiver. This increases robustness at low signal-to-noise ratios (SNRs).

Results

Thanks to the design principles mentioned, the touchControl App reliably provides a large number of useful remote control functions such as volume control, program change, tinnitus volume control or SoundBalance on a wide range of smart phones.

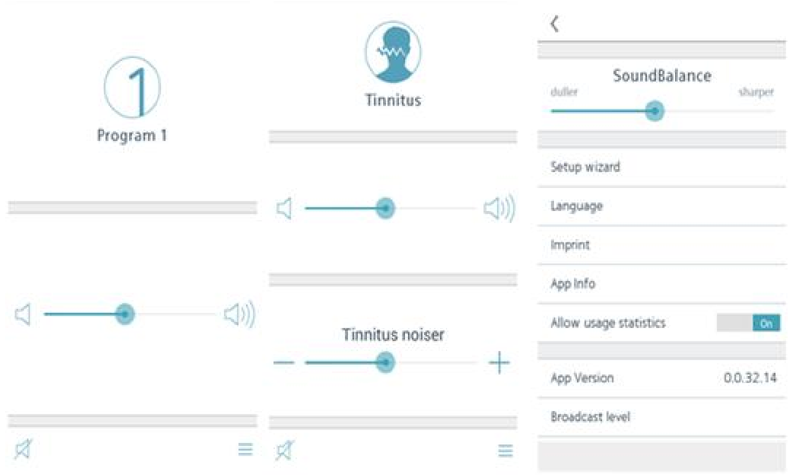

Figure 5: Program change, volume control, tinnitus control and sound balance remote control functions provided by the touchControl App on a smart phone.

Compared to wireless standards such as Bluetooth 4.0, the Acoustic Wireless Control system adds only minimal current consumption to the hearing instrument. Due to the use of the loudspeaker of the smart phone and the microphone of the hearing aid, it can be used in virtually every smart phone (the touchControl App is available for iOS and Android, which cover approximately 95% of all smart phones [4]) and all binax hearing instruments, even to instrument types which could not provide that functionality before due to unavailability of conventional wireless antennas.

References:

[1] Keidser, G., Brew, C., Brewer, S., Dillon, H.,Grant, F., Storey, L. (2005). The preferred response slopes and two-channel compression ratios in twenty listening conditions by hearing-impaired and normal-hearing listeners and their relationship to the acoustic input. Int J Audiol, 44(11), 656-670.

[2] Kochkin, S. MarkeTrak VIII: Customer satisfaction with hearing aids is slowly increasing. The Hearing Journal, Vol. 63 (1), January 2010, pp. 11-19.

[3] Rebecca Herbig, Addressing Critical Hearing Aid User Needs with Binaural Features, The Practical Benefits of Siemens binax, Siemens Whitepaper, 2014.

[4] IDC: “Worldwide Smartphone Shipments Edge Past 300 Million Units in the Second Quarter; Android and iOS Devices Account for 96% of the Global Market”, http://www.idc.com/getdoc.jsp?containerId=prUS25037214, June 2013