Hearing Aid Connectivity: Where have we been and where might we be going?

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Disclosure

• I have **relevant financial relationship(s)** with the products or services described, reviewed, evaluated, or compared in this presentation.
  – GN ReSound
    • Employed and receives salary.

• I have no relevant nonfinancial relationship(s) to disclose.
A Brief History of Wireless

- What is wireless for patients:
  - Transmission of information for many different purposes without the use of electrical conductors (wires)

- Early methods of wireless transmission include:
  - Telecoils
  - Infrared Systems
  - FM Systems
Telecoils: Probably the First Wireless System

Loop systems and telecoils work together with hearing aids to help hard of hearing people hear better.

The signal is transmitted as an electromagnetic radiation and requires a telecoil in the hearing instrument.
Telecoils & Benefits

- This system allows you to have sound - such as from the radio, TV, telephone, or public speaker - sent directly to your hearing aid with greater clarity.
- Teleloop systems in your home (e.g., television)
- Telephone
- Cinemas
- Theaters
- Houses of worship
FM Systems: The Prior Industry Standard

The person speaking wears or holds a transmitter microphone, or the transmitter is placed in the middle of the group (picking up speech from all around).

Using radio waves, the FM system sends speech signal(s) to the listener, who wears a FM receiver.
**FM Channels Tied Up until Released**

<table>
<thead>
<tr>
<th>FM1</th>
<th>USED</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM2</td>
<td>OPEN</td>
</tr>
<tr>
<td>FM3</td>
<td>USED</td>
</tr>
<tr>
<td>FM4</td>
<td>USED</td>
</tr>
<tr>
<td>FM5</td>
<td>USED</td>
</tr>
<tr>
<td>FM?</td>
<td>USED</td>
</tr>
</tbody>
</table>

**TIME**
Radio Transmission

- Any wireless radio system requires 2 basic components
  - Transmitter & Receiver
- A basic example of a radio is demonstrated by placing two small wires in proximity and flipping the current on and off
- A volt meter attached to the second loop will measure a change in the distant loop
Overview of recent wireless technologies

- Near Field Magnetic Induction (NFMI)
- Bluetooth (RF)
- Proprietary radio frequency (RF)
Overview of Wireless Technology (NFMI)

- Near Field vs. Far Field
- Far Field is similar to radio tower transmission over a broad area
- NFMI systems are designed to contain transmission energy within the localized magnetic field
  - The power density of near-field transmissions is extremely restrictive
- The carrier frequency is generally 10-14MHz
- Based upon carrier frequency and power the near and far field crossover occurs around 3-4 meters
Wireless Hearing Aid Systems Based on NFMI

- “Gateway Device” communicates between the accessory (TV, mp3 player) & the hearing aid. Typically worn around the neck.

- Uses an inductive loop to broadcast from the gateway device to the hearing instruments.
  - Similar to a t-coil but optimized to pick up field lines from the transmitter.

- Beneficial due to low current drain on hearing aids.

- Primary drawbacks are:
  - Need to wear the gateway device around the neck.
  - Sound quality can be affected by orientation of the gateway device and HA T-coil and any delay introduced by relay between components.
Overview of: Bluetooth (pre-4.0)

- Bluetooth for audio streaming introduces a delay that is likely to be unacceptable for television viewing.
- Bluetooth-based systems that stream audio use Advanced Audio Distribution Profile (A2DP).
- The latency for this protocol exceeds 40 milliseconds, and is commonly up to 125 milliseconds depending on the audio compression technique that is used.
- Combinations of the streamed sound with amplified sound or direct sound of this magnitude are perceptible as echoes and even lip synch issues when watching television.
- Even small delays, though not consciously perceived, will cause a mismatch between audio and visual signals has a significant negative impact on the television viewing experience (Reeves & Voelker, 1993).
Wireless systems based on Near Field Magnetic Induction (NFMI) combined with Bluetooth (RF)

Bluetooth radio frequency is used for communication between an accessory and a “Gateway device” and NFMI transmission is used from the “Gateway device” to the hearing instruments.
Wireless systems based on Near Field Magnetic Induction (NFMI) combined with Bluetooth (RF)

**Advantages**

- Ease of implementation due to existing Radio Frequency (RF) chips
- Longer battery life due to low current drain on hearing instruments
- Transmit through almost everything

**Drawbacks**

- Short transmission distance (max 1 meter)
- Need to wear “Gateway device” around the neck
- Sound quality can be affected by orientation of the gateway device and HA receiver coil and any delay introduced by relay between components
- May encounter interference with magnetic sources
Wireless systems based on proprietary radio frequency (RF)

- The proprietary radio frequency system uses a radio to generate an electrical wave and an antenna to send the information. In these types of systems all of the transmission energy is designed to radiate into free space. This type of transmission is referred to as “far-field”.

- The electrical wave carries the information and it can be done by using different frequencies.

- Uses ISM bands - Industrial, Scientific and Medical Frequency Band
  - 900 MHz (US, Greenland, & some eastern Pacific Islands)
  - 868 MHz (EU)
  - 2.4 GHz
ISM Bandwidths

ISM bandwidth is defined by the ITU-R (International Telecommunications Union) for radio communication.

<table>
<thead>
<tr>
<th>Frequency range [Hz]</th>
<th>Center frequency [Hz]</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.765–6.795 MHz</td>
<td>6.780 MHz</td>
<td>Subject to local acceptance</td>
</tr>
<tr>
<td>13.553–13.567 MHz</td>
<td>13.560 MHz</td>
<td></td>
</tr>
<tr>
<td>26.957–27.283 MHz</td>
<td>27.120 MHz</td>
<td></td>
</tr>
<tr>
<td>40.66–40.70 MHz</td>
<td>40.68 MHz</td>
<td></td>
</tr>
<tr>
<td>433.05–434.79 MHz</td>
<td>433.92 MHz</td>
<td></td>
</tr>
<tr>
<td>902–928 MHz</td>
<td>915 MHz</td>
<td>Region 2 only</td>
</tr>
<tr>
<td>2.400–2.500 GHz</td>
<td>2.450 GHz</td>
<td></td>
</tr>
<tr>
<td>5.725–5.875 GHz</td>
<td>5.800 GHz</td>
<td></td>
</tr>
<tr>
<td>24–24.25 GHz</td>
<td>24.125 GHz</td>
<td></td>
</tr>
<tr>
<td>61–61.5 GHz</td>
<td>61.25 GHz</td>
<td>Subject to local acceptance</td>
</tr>
<tr>
<td>122–123 GHz</td>
<td>122.5 GHz</td>
<td>Subject to local acceptance</td>
</tr>
<tr>
<td>244–246 GHz</td>
<td>245 GHz</td>
<td>Subject to local acceptance</td>
</tr>
</tbody>
</table>
Wireless systems based on Proprietary radio frequency (RF)
Where Can you Use Wireless Hearing Aids?
National restrictions:

Norway: You are not allowed to operate the equipment within 20 km of the centre of Ny Ålesund.

This product is in compliance with the following regulatory standards:


Other identified applicable international regulatory requirements in countries outside EU and US. Please refer to local country requirements for these areas.

The product is categorized as receiver category 2 according to EN 300 440.

iC: 6941C-BTB2

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada.
Ny-Ålesund, Norway

It is inhabited by a permanent population of approximately 30-35 persons. All of them work for one of the research stations — e.g. the Norwegian Polar Institute — or the logistics and supply company "Kings Bay AS", which 'owns' and runs the research village. In the summer the activity in Ny-Ålesund is greatly increased with up to 120 researchers, technicians, and field assistants. At present, Norway, the Netherlands, Germany, United Kingdom, France, India, Italy, Japan, South Korea and China[1][2] all maintain research stations at Ny-Ålesund, although not all are inhabited year-round.

From Wikipedia
# Proprietary radio frequency (RF)
## 900 & 868 MHz Wireless Technology

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Does not require a “Gateway device” for media connectivity</td>
<td>• Requires a specially designed antenna</td>
</tr>
<tr>
<td>• Long distance signal transmission</td>
<td>• Requires a streaming device for Bluetooth connectivity</td>
</tr>
<tr>
<td>• Relatively low power consumption (approx 5mA)</td>
<td>• 900 MHz ISM band is limited to use in certain areas including US, Greenland, and some eastern Pacific Islands</td>
</tr>
<tr>
<td>• Low latency (processing delay) from source to listener</td>
<td>• 868 MHz ISM band is limited to use in EU.</td>
</tr>
<tr>
<td>• No echo problems and no lip synchronization issues when watching TV</td>
<td>• Japan isn’t covered</td>
</tr>
</tbody>
</table>
Proprietary radio frequency (RF) 2.4 GHz Wireless Technology

**Advantages**

- Does **not** require a ‘Gateway Device’
- Long distance signal transmission
- Robust and reliable connections (small information packages and spread-spectrum frequency hopping which minimizes interference)
- High transmitted data capacity: bandwidth, stereo, low distortion
- Low latency (delay) so no echo problems and no lip synchronization
- World wide applicable

**Drawbacks**

- Requires a specially designed antenna
- Requires a streaming device for Bluetooth (pre 4.0) connectivity
Maintaining robust connections: Avoiding interference through small data packets
Maintaining robust connections:
Avoiding interference through frequency hopping
Avoiding interference through private communication

- When a wireless device sends data, any device in the vicinity can and will receive this data providing that it is listening in the correct way.

- Pairing occurs when two wireless devices agree to communicate and establish a private connection.

- Allows co-existence of various devices within range of each other (e.g. a streamer and telephone accessory).

- Prohibits “eavesdropping”
Wireless Accessories Available

- TV / Audio Streamer: Powered by the Wall
- Telephone Connection
- Remote Control (physical and Smart Phone based)
- Personal Microphone
Wireless Accessory Considerations

- Privacy
- Interference
- Intermediate Device Needed?
- Charging / Battery Requirements
- Frequency Response
- Direct Audio Input Options
- Stereo or Mono
- Size
- Cost
Single or Multiple Pair Streaming
Where Can a Personal Microphone be Used?

As a CROS Hearing Aid System
Thibodeau 2008, reported positive effects on the quantity and quality of parent-child interactions, as well as the children demonstrating increased interest and attention to sounds when FM systems were used with very young children.
Mini Microphone: Proof of Benefit

- Twenty test subjects with sensorineural hearing loss
  - 10 male and 10 female
  - Test subject median age is 69 (1st Quartile: 66 3rd Quartile: 76)
- Experienced with amplification (median of 20 years)
Mini Microphone: Proof of Benefit

Methods: Hardware

- Alera 967 mini BTEs. Test subjects’ hearing thresholds are all within fitting range.

- ReSound Unite™ Mini Microphone accessory.

- Test subjects use closed ear molds with venting based on their individual hearing loss.
Mini Microphone: Proof of Benefit

**Methods: Test setup**

HATS with an artificial mouth

Dantale II test sentences

HATS was placed in front of the test participant representing a hearing instrument user.

Mini Microphone was around the neck of HATS.

HATS was placed at 3 positions: 1.5, 3.0 and 6.0 meters

A diffuse noise field was generated by 6 identical loudspeakers.

The test environment was a carpeted room with a sound treated ceiling.
Mini Microphone: Proof of Benefit

Test conditions

- Testing with Dantale II was performed with the following setups:
  - Adaptive Directionality Mode
  - ReSound Unite™ Mini Microphone
  - ReSound Unite™ Mini Microphone with HI microphone active

- Test conditions and test distances were randomised for each test subject
Mini Microphone: Proof of Benefit

- **Directional Microphones**
- **Personal Mic with HA Mics**
- **Personal Mic without HA Mics**

<table>
<thead>
<tr>
<th>Distance</th>
<th>Directional Microphones</th>
<th>Personal Mic with HA Mics</th>
<th>Personal Mic without HA Mics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 Meters</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
</tr>
<tr>
<td>3.0 Meters</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
</tr>
<tr>
<td>6.0 Meters</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
</tr>
</tbody>
</table>
Mini Microphone: Asymmetric Use


- SNR benefit for wireless streaming with different test conditions using ReSound Alera wireless devices
- Eevices were programmed with 16 dB flat gain, omnidirectional response and with noise reduction off
- Speech signal from the front speaker and split to the streamer
- Party and traffic noise presented through 4 surround speakers placed at the sides/back of the test subjects
- Nine normal hearing subjects participated in the study.
Mini Microphone: Asymmetric Use

Fig. 1. Mean s/n ratios for SRT (50% correct responses) obtained in the different hearing aid settings. Vertical bars represent standard deviation.
W: wireless; M: hearing aid microphone.
The Future: The Wireless Revolution

Apple is working with the hearing aid industry to connect devices directly to hearing aids.

2.4 GHz technology is the only way to connect for real benefits.
Native Control Triple-Click Functionality

- GN’s Hearing Aids
- ReSound LN961-DRW NP

- Start Live Listen
- Right Volume 67%
- Left Volume 67%
- R + L Volume 67%
- All Around
- Restaurant
Smart App

Mute the microphone by swiping the volume slider to the bottom.
ReSound Mini Microphone: Increasing the Signal-to-Noise Ratio

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**SNR (dB)**

- **1.5 Meters**
- **3.0 Meters**
- **6.0 Meters**

**Graph Legend**

- **Blue**: Directional Microphones
- **Green**: Mini Microphone with HA Mics
- **Red**: Mini Microphone without HA Mics
Facetime: Speech Reading Opportunities
Test condition: Acoustic Phone

Unilateral Audio
Test condition:  Phone Clip+ & Audio Only

Unilateral Streaming

Bilateral Streaming
Test condition: Phone Clip+ & Audiovisual

Unilateral Streaming

Bilateral Streaming
Test condition: iPhone & Audio Only

Unilateral Streaming

Bilateral Streaming
Test condition: iPhone & Audiovisual

Unilateral Streaming

Bilateral Streaming
FaceTime: Proof of Benefit

- 15 severe-to-profound hearing-impaired individuals (10 male & 5 female)
- Median age: 77 years
FaceTime: Proof of Benefit

- Testing was done in a sound treated room with a loudspeaker setup as shown below:
FaceTime: Proof of Benefit

- Test material: Dantale I speech material
- Procedure
  - 9 phone conditions completed over 2 sessions (counterbalanced)
  - Each session initiated with two training rounds; one being the audio only signal and one being the audiovisual signal
  - Percentage correct score for each test condition
Benefit of Unilateral Audio Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic Phone Audio Unilateral</td>
<td>6%</td>
</tr>
<tr>
<td>Phone Clip+ Audio Unilateral</td>
<td>45%</td>
</tr>
<tr>
<td>MFi Audio Unilateral</td>
<td>45%</td>
</tr>
</tbody>
</table>
Benefit of Bilateral Streaming

Mean Percent Correct

Unilateral Streaming: 55%

Bilateral Streaming: 65%
Benefit of Visual Information

Mean Percent Correct

- Audio: 48%
- Audiovisual: 71%
Menu & My hearing aid

- My places
- My hearing aid
- Tutorial
- Settings

Quick start
- Inserting/removing hearing aids with moulds
- Program button
- Battery size and replacement
Finder
Bass / Treble Adjustments
GeoTagging
More Future Options

- Smart Phone as data storage for hearing aid
- Smart Phone as signal processor for hearing aid
- Smart Phone for Habilitation / Rehabilitation programs
- Tinnitus Solutions