WIRELESS HEARING ASSISTIVE TECHNOLOGY DEMYSTIFIED

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LEARNING OBJECTIVES

1. Describe the differences between current wireless hearing assistive technologies.
2. Discuss how these technologies are implemented by various manufacturers.
3. State the advantages and disadvantages of different wireless hearing assistive technologies.
I. What is WHAT and Why is WHAT Needed?

II. Wireless Technology Overview and Comparisons

III. WHAT Selection Considerations

IV. WHAT Options

V. WHAT Verification
I. What is WHAT and Why is WHAT Needed?
**What is Wireless Hearing Assistive Technology (WHAT)?**

Various types of wireless auditory technologies designed to improve communication by enhancing accessibility to the speech signal when personal hearing aids/cochlear implants are not enough.

<table>
<thead>
<tr>
<th>Wireless Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrared</td>
</tr>
<tr>
<td>FM</td>
</tr>
<tr>
<td>Induction</td>
</tr>
<tr>
<td>Digital Radio Frequency (RF) Systems</td>
</tr>
</tbody>
</table>
Couple Carry Catch

Microphone or Electrical Connection → Transmitter → Receiver → Coupling to Ears/Hearing Aid/Implant

Wireless Technology
Factors That Impact the SNR

- **Background noise**
  - Masks important sounds
- **Reverberation**
  - Smears speech signal
- **Distance between the speaker and the listener**
  - Reduces audibility
- **All of the above and the synergistic effects among these factors**
- **Directional Mics**: SNR improvement of only 3-4 dB for many difficult listening situations (Pumford et al, 2000)
WHY WHAT WORKS TO IMPROVE THE SNR

Principles of remote microphone placement
The Importance of WHAT

The American Academy of Audiology (AAA) and International Hearing society (IHS) Best Practices Recommendations consider the use of WHAT to be critical for successful intervention outcomes.

Hearing Healthcare Providers are the gatekeepers with the primary responsibility to introduce and make patients aware of WHAT and other important technology such as the telecoil.
## WHAT APPLICATIONS

### Live, Face-to-Face Communication
- Home
- Restaurant
- Meetings
- Places of worship
- Classroom
- Conferences
- Automobile
- Courtroom

### Reception of Broadcast and other Electronic Media
- Radio
- Television
- Movie theatre
- Audio player
- Computer (webinar)
- Video conferencing
- Tablet

### Telecommunication
- Smartphone
- Landline phone
- VOIP calls
- Conference calls

ANYWHERE SNR IMPROVEMENT IS DESIRED!
II. WIRELESS TECHNOLOGY OVERVIEW AND COMPARISONS
**Digital Wireless RF Technology**

Its use in hearing aids/cochlear implants serves three functions:

<table>
<thead>
<tr>
<th>Communication between hearing aids/CIs (ear-to-ear) for synchronized processing and control of program and volume changes</th>
<th>Communication with a remote control</th>
<th>Streaming of audio/speech from devices such as telephones, computers, microphones, personal music players, and communication partners = WHAT</th>
</tr>
</thead>
</table>

Let's Set the STAGE
ELECTROMAGNETIC (EM) WAVES

The Electromagnetic Spectrum

Galster, 2015
Digital Wireless Technology Used in Hearing Aids/CIs

☆ Near Field
  ★ Near Field Magnetic Induction (NFMI – 4-14 MHz)
  ★ Range: 1 meter

☆ Far Field
  ★ Bluetooth (2.4 GHz – 2.48 GHz)
    ★ Range: 10 meters (class 2)
  ★ 2.4 GHz
    ★ Range: 20-25 meters
  ★ 900 MHz
    ★ Range: 5-7 meters
Illustration of relative field strength as a function of distance for near-field magnetic induction and far-field transmission methods.
FREQUENCY HOPPING SPREAD SPECTRUM

- Used to combat interference
- The signal “hops” among various frequencies within the bands to choose the frequency with the least interference
- Ensures that large numbers of devices can coexist in a small area without the need for manual selection of frequency channels
What is NFMI?

★ Near Field Magnetic Induction
  ★ Magnetic field remains relatively localized around the transmitting device – up to 1 meter

★ NFMI benefits: Low power, low cost, small components, signal not blocked or reflected, and secure transmission medium
  ★ Commonly used for ear-to-ear communication
  ★ Not suitable for far field transmission
How Does NFMI Work?

- **Principle of magnetic induction**
  - NFMI systems incorporate an induction transmitter in the gateway device
  - A magnetic field is generated on a carrier frequency and digitally modulated
  - Induction receive in the HA demodulates this signal
  - Communication can be 2-way
    - The NFMI unit can act both as a receiver and as a transmitter
**The Gateway or Relay Device**

- Uses one technology to communicate with the WHAT accessory and then converts the signal into another format for retransmission to the hearing aid.
- Permits bi-directional transfer of audio communication.
- Multiple functions may be combined into the relay device:
  - Transceiver for streamed audio signal
  - Remote control
  - Direct connection to audio sources
Proprietary NFMI Systems

★ Advantages:
  ★ Easy to implement in hearing aids/CIs
  ★ Suitable for ear-to-ear communication
  ★ Reduced power demands on the hearing aids/CIs = better battery life

★ Disadvantages:
  ★ Short transmission distance
    ★ Need to be combined with a far field wireless signal (Bluetooth or proprietary RF)
  ★ Requires use of a gateway device worn on or close to the body
  ★ Degraded sound quality due to increased audio latency when combined with Bluetooth audio transmission
2.4 GHz

FCC opened the 2.4 GHz band to public use in 2001, resulting in an influx of products that use this band.

Permits far field wireless transmission but not suitable for near field (ear-to-ear).

While Bluetooth also operates in this frequency band, it uses a specific protocol architecture that is unique from other wireless technologies also in this band.

2.4 GHz has less audio latency delay compared to BT.
900 MHz ISM Band

UHF radio system operating on 900 MHz (ISM band)

Allows for both far-field wireless audio streaming and near-field ear-to-ear binaural processing

Advantages
• Unlimited number of hearing aids can access a single transmitter without the need for pairing

Limitations
• Not internationally accepted, cannot use in Europe, Japan and other countries
• Lower RF signals require a longer antenna
Proprietary 2.4 GHz and 900 MHz Systems

★ Advantages
★ Far field technologies
★ Can transmit directly to the hearing aid without the need for a gateway device
★ Minimal delay of streamed audio
★ Point-to-multipoint

★ Limitations
★ Higher power consumption compared to NFMI systems
What is Bluetooth?
BLUETOOTH HISTORY

Developed in 1994 by a group of engineers working at Ericsson

Designed to be:
- A unified standard for cell phones and computers to communicate
- Cable Replacement Technology

Almost called “Flirt” – tag line was to be “Getting close without touching”
**Why is it Called Bluetooth?**

- Named after the 10th Century Danish Viking king, Harald Blåtand, known for his unification of warring tribes from Denmark including Skåne (present day Sweden)
  - Blåtand translated into English is “Bluetooth”
- Like its namesake, Bluetooth is intended to unify the many electronic devices marketed by the telecommunication and computing industries
- BT symbol verifies device is BT-enabled
What is Bluetooth?

- Globally operates on the unlicensed, Industrial Scientific Medical (ISM), low power microwave band at 2.402 GHz – 2.485 GHz
- Radio-based technology that allows wireless connectivity and data/audio exchange between multiple Bluetooth-enabled devices through personal area networks (PAN)

Advantages
- Robustness
- Low-cost
- Security
- Portability
- Multiple users can be in the same room using BT
THE BLUETOOTH NETWORK TOPOLOGY

- A Piconet consists of Master and Worker devices
- Piconet:
  - Ad hoc network group of up to 8 active devices
    - Master + 7 Workers
  - While a device can be paired with multiple devices, it can only be connected to one device at a time
**BT is similar, but not the same as, 2.4 GHz**

- **BT is a radio frequency standard or protocol**
  - Offers a predefined method of exchanging data between multiple devices
  - Two BT compatible devices connected via BT must meet certain requirements before they can exchange data
  - Devices must agree on the scheduling and packaging of bits of data
  - Devices must support the same BT protocols
Just because you have devices that each use Bluetooth does NOT mean they will work together to accomplish the same goal.
Bluetooth Application Profiles

To use Bluetooth technology, a device must be able to interpret certain Bluetooth protocols or rules; the profiles define the possible applications of a BT device.

Think of profiles as capabilities or features.

The BT Device must support the appropriate Bluetooth profile of the Bluetooth transreceiver.
Bluetooth Profile Soup

Advanced Audio Distribution Profile (A2DP), Attribute Profile, Audio / Video Control Transport Protocol (AVRCP), Basic Imaging Profile (BIP), Basic Printing Profile (BPP), Common ISDN Access Profile (CIP), Cordless Telephony Profile (CTP), Device ID Profile (DIP), Dial-Up Network Profile (DUN), Fax Profile (FAX), File Transfer Profile (FTP), Generic Audio/Video Distribution Profile (GAVDP), Generic Access Profile (GAP), Generic Attribute Profile (GATT), Generic Object Exchange Profile (GOEP), Hard Copy Caple Replacement Profile (HCRP), Health Device Profile (HDP), Human Interface Device Profile (HID), Hands-Free Profile (HFP), Hard Copy Cable Replacement Profile (HCRP), Headset Profile (HSP), Intercom Profile (ICP), LAN Access Profile (LAP), Mesh Profile (MESH), Message Access Profile (MAP), Object Exchange (OBEX), Object Push Profile (OPP), Personal Area Networking Profile (PAN), Phone Book Access Profile (PBA), Proximity Profile (PXP), Serial Port Profile (SPP), Service Discovery Application Profile (SDAP), SIM Access Profile (SIM), Synchronization Profile (SYNCH), Video Distribution Profile (VDP)…….
**Bluetooth Application Profiles to Look for**

**HSP Headset Profile (most common)**
- Provides support for BT headsets to be used with cell phones
- Allows the ability to ring, adjust the volume, answer a call and hang up

**HFP Hands-free Profile**
- Used by BT headsets for hands-free calling
- Commonly used to allow communication with a car hands-free system
- The extra features that HFP allows are last number redial, call waiting, and voice dialing

**Most BT headsets support both HSP and HFP profiles**
A2DP Advanced Audio Distribution Profile

- High-end audio profile with broader bandwidth and stereo capabilities
- Defines how high-quality audio (stereo or mono) information can be streamed from one device to another
- Examples:
  - Music from mobile phone to a car audio system or a wireless headset
  - Music from an MP3 player to a wireless headset
  - Audio from a TV/stereo, computer to a wireless headset
PROFILE CONFUSION – TELEPHONE CALL

Supported BT Profiles: HSP/HFP

Profiles: HSP/HFP/A2DP
**Profile Confusion – Listen to Music**

Roger Select

Supported BT Profiles: HSP/HFP

Profiles: HSP/HFP/A2DP
PROFILE CONFUSION – LISTEN TO PHONE & MUSIC

Supported BT Profiles: HSP/HFP/A2DP

Oticon Connect Clip

Profiles: HSP/HFP/A2DP
CLASSIC BLUETOOTH SYSTEMS

**Advantages:**
- Widely available
  - Permits use of 3\textsuperscript{rd} party BT devices
- Point-to-point technology
  - Communication between devices is direct and secure

**Limitations:**
- High current demand = reduced battery life
- Typically requires a gateway device
- Increased audio latency can degrade the signal
- Requires pairing routines
- Use is restricted to the paired devices
  - Point-to-multipoint application limited
Bluetooth Smart (BT Low Energy-BLE) advantages include reduced transmission delay and battery drain compared to classic BT

- Eliminated the ‘audio’ channel to allow for fast and efficient transmission of data only

Apple Low Energy Audio (LEA)

- Apple collaborated with HA industry to connect devices directly
- Developed a special language to allow hearing aids with a 2.4 GHz antenna to communicate with Apple products and allow the transmission of audio information
ASHA (Audio Streaming for Hearing Aids)

- New hearing aid spec for Android smartphones using BLE, that will eliminate the need for a relay device
  - Battery efficient
  - Low latency
- GN ReSound is working on building native hearing aid support for Android in the LiNX Quattro
- The protocol specification is published and available for any HA manufacturer to use
  [https://source.android.com/devices/bluetooth/asha](https://source.android.com/devices/bluetooth/asha)
III. WHAT SELECTION CONSIDERATIONS
# WHAT SELECTION CONSIDERATIONS

## Intended Use
- Face-to-face communication
  - Single vs. multiple speakers
- Broadcast media
  - Equipment type
  - Need to direct connect to non-wireless devices
- Telecommunication
  - Smartphone
  - Landline (BT adapters)

## Device Performance
- Battery drain
- Transmission delays
- Transmission range
- Point-to-point vs. Point-to-multipoint
- Multimic Networks

## End-User Preferences
- Budget
- Preferences
  - Gateway vs. no gateway
- Ease of use
- Device specific vs. non-proprietary products
Typical Product Current Drain

Data Sheets vs. Actual Current Drain

- **Product A (2.4GHz)**: 1.97
- **Product B (2.4GHz)**: 1.9
- **Product C (2.4GHz)**: 1.5
- **Product D (2.4GHz)**: 2.4
- **Product E (900MHz)**: 1.5
- **Product F (NFM)**: 1.4
- **Product G (NFM)**: 1.3

**Current Drain**

- **Data Sheet**
- **No Stream**
- **Stream**
TRANSMISSION DELAY OR AUDIO LATENCY

★ What is it?
★ The amount of time between when audio data leaves your device and when you actually hear it
★ Excessive delays
  ★ May cause a lack of synchrony between the video and streamed audio
  ★ May cause perceived echoes between the direct sound and streamed sound
★ How much delay is too much delay??
Transmission Delay
EXCESSIVE TRANSMISSION DELAY

Using Bluetooth for audio streaming introduces a delay that is likely to be unacceptable for certain applications (e.g. remote mic, television viewing)

- Bluetooth has approximately 3x the latency of wired audio
- The latency for the A2DP BT protocol exceeds 40 milliseconds, and is commonly up to 125 milliseconds depending on the audio compression technique that is used

Hybrid transmission (BT to NFMI) is an additional limitation; adds another 10 ms delay
There are three signal paths to consider when live listening with a wireless streaming device.

1. Direct path (unamplified path)
   - No delay

2. Indirect path (HA amplified path)
   - Group delay introduced by the processing of the HA

3. Indirect path (wireless streaming path)
   - Wireless streaming delay

Hearing aid coupling (open vs. closed) will be a factor.
OPEN-FIT HEARING AIDS

- With open-fit hearing aids, both the direct non-amplified pathway and indirect amplified pathway are heard by the wearer in addition to the streamed signal.
  - Direct, unamplified pathway arrives sooner than the indirect amplified audio and streamed audio.
Whitmer et al., 2011

Benefit of a wireless system was resistant to delay up to 20 ms.

Speech intelligibility was affected by:

- Open-fit: was resistant to transmission delay
- Closed-fit: transmission delays ≥ 40 ms

Open coupling diminished performance and no benefit was found with a delay of 80–160 ms.

Speech intelligibility was affected by:

- Open-fit: was resistant to transmission delay
- Closed-fit: transmission delays ≥ 40 ms
TRANSMISSION DELAY (MS)

That was then... This is now
Audio Latency: Remote Mics

Transmission Delays-Remote Mics

- Phonak
- Oticon
- Widex
- Phonak
- Oticon
- ReSound
  2.4 GHz
- Signia
- Starkey
- Starkey
  900 MHz
Delay varies with TV (analog, digital, Dolby digital). Shown are the lower values for analog.
Transmission Range: Remote Mics

Transmission Range: Remote Mics

<table>
<thead>
<tr>
<th>Device</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonak Bluetooth</td>
<td></td>
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<tr>
<td>Widex</td>
<td></td>
</tr>
<tr>
<td>Phonak</td>
<td></td>
</tr>
<tr>
<td>Oticon</td>
<td></td>
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<tr>
<td>Oticon</td>
<td></td>
</tr>
<tr>
<td>ReSound 2.4 GHz</td>
<td></td>
</tr>
<tr>
<td>Signia</td>
<td></td>
</tr>
<tr>
<td>Starkey</td>
<td></td>
</tr>
<tr>
<td>Starkey 900 MHz</td>
<td></td>
</tr>
<tr>
<td>Oticon Analog FM</td>
<td></td>
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</tbody>
</table>
Transmission Range: TV Transmitters

Transmission Range-TV Transmitters

<table>
<thead>
<tr>
<th>Brand</th>
<th>Frequency</th>
<th>Range (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonak</td>
<td>2.4 GHz</td>
<td>30</td>
</tr>
<tr>
<td>Oticon</td>
<td>2.4 GHz</td>
<td>30</td>
</tr>
<tr>
<td>Signia</td>
<td>2.4 GHz</td>
<td>15</td>
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<tr>
<td>Phonak</td>
<td>900 MHz</td>
<td>6</td>
</tr>
<tr>
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<td>2.4 GHz</td>
<td>6</td>
</tr>
<tr>
<td>ReSound</td>
<td>2.4 GHz</td>
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<tr>
<td>Widex</td>
<td>2.4 GHz/NMFI</td>
<td>6</td>
</tr>
<tr>
<td>Signia</td>
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</tr>
<tr>
<td>Starkey</td>
<td>900 MHz</td>
<td>6</td>
</tr>
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<td>6</td>
</tr>
<tr>
<td>Widex</td>
<td></td>
<td>6</td>
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</tbody>
</table>
IV. WHAT OPTIONS

Face-to-Face Communication
Broadcast Media
Telecommunication
CURRENT DIGITAL WIRELESS HA/CI TECHNOLOGIES

★ Hybrid approaches:
  ★ Require a relay device (gateway) to link the WHAT accessory to the hearing aids/cochlear implant.
    ★ NFMI combined with Classic Bluetooth radio frequency (RF) transmission
    ★ NFMI combined with proprietary RF transmission (2.4 GHz)

★ Direct approaches:
  ★ Send the signal directly from the WHAT accessory to the hearing aids/cochlear implants; no gateway device
  ★ Proprietary RF transmission alone (2.4 GHz, 900 MHz)
  ★ Classic BT or BLE alone
Couple

Carry

Catch

Mic

TV

Mic

TV

Bluetooth

Proprietary NMFI

Neck/lapel worn gateway (transceiver)

Proprietary 2.4 GHz or 900 Mz
<table>
<thead>
<tr>
<th>BT/NMFI TV Transmitters</th>
<th>Phonak TVLink II</th>
<th>Oticon ConnectLine TV</th>
<th>Signia easyTek TV Transmitter</th>
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</thead>
<tbody>
<tr>
<td>BT Profiles</td>
<td>A2DP</td>
<td>A2DP</td>
<td>A2DP</td>
</tr>
<tr>
<td>Transmission range</td>
<td>30 m</td>
<td>30 m</td>
<td>4.5 m</td>
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<tr>
<td>MultiConnect</td>
<td>No</td>
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<tr>
<td>Bandwidth</td>
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<td>Mono/Stereo</td>
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<td>Mono</td>
<td>Stereo</td>
</tr>
<tr>
<td>Audio Latency</td>
<td>40 ms</td>
<td>Analog 37 ms Digital 39 ms Dolby Digital 59 ms</td>
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</table>

**Notes:**
- **A2DP** refers to the Advanced Audio Distribution Profile.
- **MultiConnect** indicates whether the device is compatible with multi-codec connections.
- **Bandwidth** refers to the frequency range of the audio transmission.
<table>
<thead>
<tr>
<th>2.4 GHz TV Transmitters</th>
<th>Phonak TV Connector</th>
<th>Oticon TV Adapter 3.0</th>
<th>ReSound TV Streamer2</th>
<th>Widex TV Play</th>
<th>Starkey TV Streamer</th>
<th>Signia Streamline TV</th>
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Phonak Roger Advantages

Better

Poorer

Thibodeau 2014

Roger
Wolfe at al, 2015

- Compared ReSound MicroMic and Phonak Roger Pen
- Both RM technologies were significantly better compared to HA-alone, even in quiet
- In quiet and at 55 dBA, the Phonak Roger and ReSound MicroMic performed similarly
- As the noise level increased, the Phonak Roger Pen performed significantly better than the ReSound MicroMic and this difference in benefit was the greatest at the high noise levels (75, 80 dBA)
LINKING TO OTHER AUDIO/MEDIA SOURCES

1. Non-BT-enabled device
   a) Attach a BT transmitter/adapter
   b) Use BT gateway device that supports the BT profile (e.g. A2DP)

2. BT wireless connection
   a) Pair and connect gateway to 3rd party BT devices
   b) Apple products will work with Mfi aids w/o gateway

3. Hardwired—direct connection
**Computer Connections**

- **BT built into laptop or PC paired to gateway device**
- **If not A2DP supported**
  - Sennheiser BTD500 USB, BT800 BT dongle
- **Hardwired to gateway device via 3.5mm input/output jack**
Couple

Carry

Catch

Bluetooth

Proprietary NMFI

Phonak EasyCall

Direct Connect

Proprietary NMFI

Widex CallDEX

Bluetooth

Induction

ClearSound Quattro
**PHONAK AUDEO B-DIRECT and UNITRON MOXI ALL (ANY BT PHONE)**

- MFA = Made-for-All
- Uses classic BT
- Phone calls are mono – stream to only one aid
- No support for A2DP
  - Cannot stream music
  - Streaming for phone calls only (HFP)
- True hands-free calling
  - Answer/ending calls via HA
  - Picks up your voice using onboard HA microphones
First hearing aid capable of streaming audio and phone calls to DIRECTLY to each hearing aid for BOTH iPhone and Android BT-enabled phones
**How Does it Work?**

- Classic BT can only stream to one ear
- Phonak developed a proprietary algorithm to allow streaming to both ears
- One aid (RE by default) is paired and connected to the phone = Master
- Master shares pairing ID and key with the Assistant (LE) to route audio to that HA
- Can change Master in Target software
BT Pairing – Uses BT Menu

[Images of device interface showing Bluetooth settings]

Now discoverable as "Ingrid McBride's iPhone".

MY DEVICES
- Car Multi-Media: Not Connected
- HandsFreeLink: Not Connected
- Ingrid's Apple Watch: Connected
- Ingrid's BeatsX: Not Connected
- JBL Flip 2: Not Connected
- Office Speaker: Not Connected
- R-phonak hearing aid: Connected

[Phone interface showing call log]

(602) 578-9541
00:01

[Options to set as speaker]

Let's Set the STAGE
Landline BT Phones

- Phones with built-in BT
  - AT&T has several models
  - ClearSounds iConnect A1600BT Amplified Phone with BT
  - CapTel 2400iBT captioned phone
- Will only work with BT gateway devices or direct to Phonak Marvel
PROPRIETARY NFMI PHONES

- NOT BT phones
- Landline cordless phones that use NFMI to stream directly to both hearing aids (e.g. Widex PhoneDEX2, Phonak DECT CP1)
**LINKING TO LANDLINE PHONES**

- Variety of BT adapters that can work with any BT gateway device
- Check BT Profiles and phone compatibility
- Plantronics MDA200 with BT300 Bluetooth adapter
  - Works with analog or digital phones and/or computer
  - Supports A2DP

Oticon Phone 2.0

Plantronics MDA200 with BT300 Bluetooth adapter
Binaural Advantages of WHAT

- Two main advantages to wireless phone streaming
  - Hands-free phone use
  - Significantly better speech recognition for wireless bilateral presentation vs. unilateral speech presentation with phone use (Picou & Ricketts, 2010, 2013)
V. WHAT VERIFICATION
WHAT VERIFICATION

Electroacoustic verification to ensure proper device programming is essential with hearing aids and WHAT accessories.

Verification is possible for ALL these additional inputs to the hearing aids:

- Telecoil
- Roger/FM
- Remote Mics (other than Roger)
- TV transmitters
- Smartphone
Verification Goal = Acoustic Transparency

Acoustic Transparency of the mic response with hearing aid response with alternative inputs (telecoil, RM, TV transmitter, phone, etc.)

Condition in which equal inputs to the WHAT accessory and local mics generate equal outputs from the hearing device.
ADDITIONAL GOALS OF WHAT FITTING

1. Audibility of the input to the WHAT accessory
2. Audibility of others at a variety of distances who are not picked up by the accessory
3. Audibility of self
**WHY WHAT VERIFICATION IS NEEDED**

- Electroacoustic characteristics of the hearing aid can change significantly when the telecoil or WHAT accessory is activated
- Default telecoil/WHAT accessory response may or may not be appropriate
  - Output of the telecoil/WHAT accessory can be weaker or stronger than the microphone mode
  - Requires the user to adjust the volume control (if one exists) when using the telecoil/WHAT accessory
WHAT TRANSPARENCY VERIFICATION THREE STEP

- Need a HAT box (Verifit, Fonix, or other)
- All measurements are done in WHAT accessory + Mic mode, but only one signal path is tested at a time
  - Goal = 65 dB SPL input to HA = 65 dB SPL input to WHAT accessory
STEP 1: HA RESPONSE

- Test hearing aid using a 65 dB SPL input without the RM receiver attached (primary acoustic program)
  - Disable noise reduction and FB canceling in HA; use omni mic mode
- Verify that the HA has been set appropriately for the patient’s individual degree and configuration of hearing loss
**Step 2: RM Response**

- Go to RM + Mic program (via software or app)
- With HA still attached to the 2cc coupler, place the HA outside of the test box (mute HA mic)
- Unmute the RM transmitter and place mic in the test box
- Evaluate RM response with 65 dB SPL input to the RM
- Compare the two output responses
  - Any difference is the RM offset
  - Determine if changes are needed or if transparency has been achieved
  - Transparency = ± 2 dB
STEP 2 – REMOTE MIC PROGRAM

Pre-Programming

Post-Programming

Transparency achieved
**Step 3: Mic Response**

- Hearing aid back in test box
- RM transmitter out of test box
- Measure mic response in the RM+Mic program
- Main goal:
  - Ensure environmental mic is not too loud
  - Make transparent
**OPTIONAL STEP**

- Remote mic in test position
- Change instrument to “FM”
- Inputs a louder signal typical of a closer microphone placement (e.g. 80 dB SPL)
- Demonstrates the RM Advantage
SAME THREE STEPS FOR PHONE

★ Use landline or smartphone
★ Place phone microphone near reference mic
★ Call patient’s smartphone
★ Complete Steps 1-2-3 to verify
  ★ Loudness of streamed signal
  ★ Loudness of environmental mic
SAME THREE STEPS FOR TV TRANSMITTER

★ Step 1--same
★ Step 2:
  ★ Connect TV Streamer to rear of Verifit
  ★ Use on-ear measures
  ★ Set to OPEN, equalize once with internal speaker
  ★ Change to external speaker (routes test signal to TV transmitter)
  ★ Complete measurement/adjustment
★ Step 3: same
TELECOILS – AN IMPORTANT TRANSUCER

- Ferrite metal rod encircled with coils of copper wire that is sensitive to magnetic fields
- Converts electromagnetic energy to electrical signals for processing in the HA/CI
- Wirelessly picks up electromagnetic energy from a source through the process of induction
- Produces a voltage when an alternating magnetic field flows through it
- Also known as T-Coil, induction pickup coil, audio coil, magnetic induction system
The Versatile Telecoil

- This tiny transducer provides the user with greater access to:
  - Telephone coupling
    - Landline and cell phones
  - Hearing Loop Systems
  - Coupling to HAT receivers and other audio sources via induction neckloop or induction silhouette
**Principles of Electromagnetic Induction**

- When an electric current passes through a metal coil or loop of wire it generates an alternating magnetic field that has the same waveform as the original signal.
- Conversely, when a magnetic field passes across a coil (such as a telecoil) it induces an electrical voltage in the coil.
- The process of an electrical current inducing a voltage in a coil some distance away is called induction.
**Telecoil Orientation**

- To obtain optimal performance, the telecoil axis should be oriented parallel to the axis of the electromagnetic radiation
  - Phone: horizontal orientation
  - Loop system: vertical orientation
**TELEPHONE ORIENTATION**

- Horizontal orientation is the most optimal for phone use; however, most hearing aids use a vertical orientation.
- Most users therefore require instruction to learn how to correctly position the phone over the telecoil’s “sweet spot.”
- This is especially true for BTE users.
**VERTICAL COIL – POSITION EFFECTS**

- Holding the phone directly on the side of the aid where it is perpendicular to the coil will yield a significant drop in signal.
## The Versatile Telecoil - Advantages

<table>
<thead>
<tr>
<th>Standard in most hearing aids; added cost is minimal if optional</th>
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</thead>
<tbody>
<tr>
<td>No acoustic feedback</td>
</tr>
<tr>
<td>No amplification of acoustic energy; greater SNR on phone</td>
</tr>
<tr>
<td>Virtually no battery drain</td>
</tr>
<tr>
<td>Better low frequency response</td>
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<tr>
<td>No additional receiver needed with ILS</td>
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<tr>
<td>Link to HAT and other audio devices via neckloop/silhouette</td>
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<td>Good workplace option</td>
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<td>No transmission delay</td>
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</table>
The Versatile Telecoil – Disadvantages

- Interfering electromagnetic sources
- Requires the use of HAC phones
- Adds to size of hearing aid
- Positioning of phone takes practice
- Typically hear out of only one ear
  - Telecoil-enabled accessories will permit signal routing to both ears
- Frequency response may be different from mic response unless programmed
**WHAT IS TELECOIL VERIFICATION?**

- Objective measurement of the performance of the hearing aid in the telecoil mode in relation to a prescriptive target using a level controllable standard inductive signal source
- Requires a test box that contains a loop to generate a magnetic field
- Verification goal:
  - The telecoil frequency response should match the microphone frequency response for seamless transition from one mode to the other
  - In other words, a 0 dB difference between M and T programs
Verifying the Telecoil Response: Phone Use
Verification Needed for Loops Too

Pre-programmed response

Post-programmed response

Mic

Telecoil
Differences were noted both within and across manufacturers.

Out of the 35 aids tested, 74% failed to meet a transparency criterion of $\pm 5$ dB at one or more frequencies from 400 Hz to 3000 Hz.

Post-programming, 91% of the 35 aids tested met the transparency criterion of $\pm 5$ dB at one or more frequencies from 400 Hz to 3000 Hz.

McBride, 2016
Default Telecoil Responses

- Default transparency was better for the telecoil-loop; however, differences were noted both within and across manufacturers.
- Out of the 35 aids tested, 46% failed to meet a transparency criterion of ± 5 dB at one or more frequencies from 400 Hz to 5000 Hz.
- Post-programming, 94% of the 35 aids tested met the transparency criterion of ± 5 dB at one or more frequencies from 400 Hz to 5000 Hz.

McBride, 2016
MT CHALLENGES

- The default microphone response was often not only louder than the telecoil response but louder than the microphone response in the primary program
  - The default mixing ratio (e.g. 0 or -6 dB) was not what was measured
- Not every manufacturer has the ability to attenuate the microphone in the MT program
- When adjustable it is a simple attenuation relative to the mic
- The mic attenuation control was found to not work at all in at least one manufacturer
MIC + TCOIL MODE

★ The default microphone setting in the MT program was typically louder than the telecoil response; differences were noted both within and across manufacturers

★ Out of 27 (8 did not have an MT option for phone) aids tested, 59% failed to meet a transparency criterion of $\pm 5$ dB at one or more frequencies from 400 Hz to 3000 Hz

★ Out of the 35 aids tested, 34% failed to meet a transparency criterion of $\pm 5$ dB at one or more frequencies from 400 Hz to 5000 Hz
**MT Challenges**

- Adjusting the mic/telecoil mixing ratio was not always successful.
- Post-adjustment, 67% of the MT responses for phone and 37% for loop failed to meet the transparency criterion.
MT CHALLENGES

- With this aid, the MT mic response was below the telecoil response set for telecoil loop as well as the mic response for the primary program.
- Since the default mixing ratio was 0 dB there was no way to increase the MT mic response.

Microphone response of MT program at default 0 dB mixing ratio
Contains an integrated telephone magnetic field simulator (TMFS) and a telecoil test loop meeting the requirements of ANSI S3.22 2009 that enable the measurement of coupler SPL produced by a HA with a telephone pickup coil. Faceplates are parallel to the floor of the test box chamber for telephone verification and perpendicular to the floor of the test box chamber for loop verification.
VERIFIT SPEECHMAP: TELECOIL VERIFICATION – PHONE COIL

Pre-programming

Post-programming
**VERIFIT SPEECHMAP: TELECOIL VERIFICATION – LOOP COIL**

- **Pre-programming**
- **Post-programming**
**Verifit 2 – Tele-test Handset**

Uses a 56.2mA/m stimulus (equivalent to 65 dB SPL acoustic stimulus)
Can attach a magnet to test autocoils
Can verify 2 aids simultaneously
Allows verification of binaural streaming of the telecoil (e.g. Duo Phone)
Some gateway devices incorporate an induction receiver to allow users to take advantage of ILS.

This is advantageous since some hearing aids do not or cannot have a telecoil (e.g. CIC or some RICs):

- Siemens miniTek
- Widex M-Dex
- Oticon Streamer Pro

You can verify the telecoil response with this arrangement as well.
TELECOIL PROGRAMMING OPTIONS

Telephone versus loop
★ Dedicated telecoil programs
★★ Phone telecoil
★★ Loop telecoil
★ The same telecoil response may not be appropriate for both applications

Telephone versus microphone
★ Tcoil-only
★ Tcoil-plus-microphone
★★ Remember to verify the microphone response
★★ Attenuate mic response as needed
T- COIL OPTIONS: AUTO VS. MANUAL

- Telecoil can be accessed manually by switching to the T-coil program via program button or remote control
- Auto telecoil: reed switch in HA automatically switches to the T-Coil program when triggered by the detection of a static magnet
  - For phone use only
  - Useful for patients who cannot manipulate a manual tcoil switch or button
  - Auto telecoils WILL NOT work with neckloops, silhouettes, or induction loop systems

Rarely give a patient ONLY an automatic telecoil; this severely limits the functionality of the telecoil