Maximizing Technology for Children with Hearing Loss: Verification of Hearing Aids, FM Systems, and Cochlear Implants

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Acknowledgements
- Phonak
- Cochlear
- Frye Electronics
- Plano Regional Dayschool Program for the Deaf
- Students: Erin Schafer, Gary Overson, Holly Whalen, Jessica Sullivan, Stephanie Cox
- Murphy’s Law

Overview
FM Technology-Transmitters and Receivers
Interface with Hearing Aids
Interface with Implants
Verification
Research

Historical Review
Traditional FM System
- Teacher wears Body Worn Transmitter
- Student wears Body Worn Receivers
- Student wears Ear Level Receivers

FM Demos
- Helpful to demonstrate for teachers, parents and administrators
- Can access on the web page or from the EARRING CD ROM
- HA Only then HA+ FM in noisy classroom

www.utdallas.edu/~thib
FM Transmitter

Wireless Channel Changeability - WICC

1) Direct Frequency Synchronization - DFS
   Ex. MLxi with inspiro

2) Automatic Frequency Synchronization - AFS
   Ex. MLxi with Wall Pilot

FM Transmitter Microphone

FM Transmitter Program Capability

Phonak inspiro
   216-217 MHz
   Can program Transmitter for selected Channels
   - Rapid Charge
   - Mute for Cheek Mic

Oticon Amigo
   216-217 MHz
   Can use Transmitter to changes settings on FM Receiver
   - Stores Data
   - Programs FM Adv

Team Teaching in the Same Classroom
SMART LINK TRANSMITTER

Remote Control, Auto FM, Bluetooth

EASYLINK TRANSMITTER

Similar to SmartLink without the remote control feature WITHOUT Bluetooth

How Bluetooth Works.....

Transmission range is as short as 2 feet up to about 10 ft.

Interference is limited because of “frequency hopping”
The signal is constantly transmitted on one of 79 different randomly chosen frequencies

Devices communicate with each other through these frequencies to create a Personal Area Network or Piconet

Bluetooth available NOW in cell phones, computers, and electronic calendars.

FM RECEIVERS

STYLE...STYLE...STYLE

Compensate for the Hassle Factor!!!.....Cosmetically???
**FM TECHNOLOGY IS MOVING TO THE EAR!!!**

**ADVANTAGES**
- Less equipment on the body!
- No Pouches/Harnesses to Maintain
- No Cords to Break

**DISADVANTAGES**
- Smaller Components
- Non-rechargeable batteries
- Possibly more variety of units to accommodate personal hearing aid

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**FM Receiver Coupling Options**

- **Basic System**
  - Button Earphone
  - Headphone
  - Soundfield Speaker

- **Personal System**
  - Neckloop
  - Direct Audio Input
  - Silhouette

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**FM Systems integrated into BTE Case**

- New Nios H₂O with ML15i receiver

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**FM Receiver**

- **Phonak iLink/MLx S/Amigo**
  - 216-217 MHz
  - Synthesized Channels
  - Programmable FM Advantage

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**Direct Programmable Audio Interface (DPAI)**

- **Improvements in Pin Orientation**
  - Select from M, FM, FM+M
  - Select FM program in hearing aid

- **Hearing aids that allow setting FM options in the programming software are DPAI**

- **The FM receivers need to be programmed to work with DPAI hearing aids**

- **If Non-DPAI FM Receiver is used with DPAI hearing aid, the FM advantage may not be optimal**
Progression of FM Receivers

- Maxx 311 with MLxS
- iLink with internal FM
- eXtra with MicroMLxS
- eXtra with ML9S

Neckloop Option

- MyLink
- Synthesized channels
- Nice option to interface with new open-fit or receiver-in-the-ear (RITE) aids with i-coil

Integrated FM Receiver

**Phonak iSense**

**Ear Level FM Receiver**

For Persons with Normal hearing, Mild loss, Auditory Processing Disorder

- No Microphone
- Programmable Gain
- No Earmold

FM Receiver Settings

**Programmability of FM Advantage**

- Can adjust FM advantage of Phonak MLxS using programming interface

**EAR LEVEL FM SYSTEMS WITH COCHLEAR IMPLANTS**

- 3G Speech Processor with Phonak MLxS FM Receiver
Demo of CI Simulation

- Available on EARRING CD ROM
- Consider difficulty if background noise was added

CI Options: Three basic ways to use FM systems with CIs

1. Audio Coupling
   - Wall-mounted soundfield FM systems
   - Desktop soundfield FM systems

2. Electrical Coupling
   - Patch cords connect FM receiver to CI
   - Cable connect receiver
   - Direct plug-in of FM receiver

3. T-Coil Coupling
   - Processor has t-coil to receive electromagnetic signal from the body-worn FM system with neckloop

1. Audio Coupling
   - Wall-mounted Soundfield Systems
     - Phonic Ear FrontRow Pro
   - Desktop Soundfield Systems
     - Phonak Digimaster
     - Dynamic Sound Field System

2. Electrical Coupling: Patch Cords and Body-Worn Speech Processors
   - Most body-worn processors have an audio jack
     - SPrint processor with Easy Listener FM receiver
       - Advanced Bionics
         - HiResAuria, CI, and Platinum BTEs
         - Need Direct Connect Earhook and Direct Connect Cable
         - 3.5 mm stereo jack at other end

2. Electrical Coupling: Patch Cords to Ear-Level Speech Processors
   - Cochlear Corporation
     - ESPrit 22 and 24
     - Need accessory audio cover and accessory cable
       - Phonak Easy Listener
       - AVR Sonovation
       - Logicom CI
       - Cochlear Accessory Cable + Phonak MicroLink CI

Pictures from Schafer & Thibodeau (2004)
2. Electrical Coupling:
Patch Cords to Ear-Level Speech Processors

- MED/EL
  - TEMPO or TEMPO+
  - Need specialized cord for specific receivers
  - Sensitivity control does not affect audio mixing

2. Electrical Coupling:
Cable- Connect Receivers

- Plugs into speech processor with a cable provided by the manufacturer of the receiver
- Available for all processors

2. Electrical Coupling:
Direct Plug-In Receivers

- Several new processors allow for direct plug-in of FM receiver

  - Auria with Auria I-connect Adaptor and MicroLink MLx-S
  - ESPrit 3G with Cochlear Corporation MicroLink Adaptor and Phonak MLx-S

2. Electrical Coupling:
Direct Plug-In Receivers

- Nucleus Body-Worn Freedom and Phonak MLx
- Nucleus Ear-Level Freedom and Phonak MLx

FM receiver build into the battery

3. T-Coil Coupling

- T-coil available on some speech processors may be used with neckloop for body-worn FM receivers
- No research to support this arrangement
- Disadvantages:
  - Signal may vary with orientation of t-coil
  - May reduce low-frequency input to listener
  - T-coils add noise

Listening Check

Can listen to FM Signal to check the system.
Only with SPRINT, 3G, and Freedom Cochlear Implants
EAR LEVEL FM SYSTEMS WITH BONE ANCHORED HEARING AIDS

- **BAHA** is used for persons with chronic ear infections, congenital loss, and single-sided deafness.
- **BAHA** combines a sound processor with a small titanium fixture implanted behind the ear.
- The system allows sound to be conducted through the bone rather than via the middle ear. This is known as direct bone conduction.

**Validation**

Possible components of validation include:

- Electroacoustic
- Perceptual
- Educational
- Student-report
- Teacher-report
- Parent-report
- Equipment function

**Steps in FM Fitting**

- FM Referral (see EARRING CD ROM)
- Current Audiogram
- Make FM Recommendation
- Order Equipment
- Earmold Impressions
- FM Fitting Appointment

**Resources: Phonak eSchool Desk**

www.phonak.com/professional/

**Resources: Phonak Compatibility Guide**

www.phonak.com/professional/

**Resources:** Phonak FM Fitting Guidelines for Cochlear Implants
Steps in FM Fitting

- Evaluate the Personal Hearing Aid
  - Electroacoustically - Is it working OK?
  - Match to Target - Does it provide adequate gain/output?
- Listening Check with FM system
  - HA mic active
  - FM mic active
  - HA+FM match to HA alone?

Steps in FM Fitting

- Evaluate FM Advantage
- Evaluate Max Output
- Label Equipment
- Provide written instructions
- Inservice for teachers
- Follow-up visits

NEW TERMINOLOGY

- While in a sea of strips from the test box... it occurred to me that we needed new terms
- Start Simple... First Letter
  - E for Electroacoustic Measures
  - R for Real ear Measures
- Then...
  - HA for Hearing aid
  - FM for FM system in FM mode

Can you see Where this is Going??

Golden Rule

The most popular Acronyms must have 4 letters

We have used REUR, REAR, REIR REOR, and RESR ..... Now need:

- EHA65
- EFM/HA80
- EHA90
- EFM/HA90
- EHA/FM65
Now, I'm sure you will follow everything much more clearly!

Results re: ASHA Guidelines

These Four Curves were obtained as part of routine electroacoustic evaluation in Plano Regional Dayschool Program.
- EHA65
- EFMHA65
- EHA90
- EFMHA90

There are four basic evaluation steps!

1. HA&FM: with HA in test box - 65 dB SPL complex signal
   **EHAFM65**
2. FM&HA: with FM in test box - 65 dB SPL complex signal
   **EFM/HA65**
3. HA&FM: HA in test box - 90 dB SPL pure tone signal
   **EHAFM90**
4. FM&HA: FM in test box - 90 dB SPL pure tone signal
   **EFM/HA90**

To Evaluate FM Advantage

- Compare EHAFM65 with EFMHA65
  - Output curves should match
  - If not within +3dB adjust FM Advantage setting
- Compare EHAFM90 with EFMHA90
  - Output curves should match
  - If not within +3dB adjust Max Output setting

Steps to Verify HA and FM Outputs

1. Set HA to User Settings
2. Set Test Equip for Complex Signal
3. Set Test Equip to display OUTPUT, not gain
4. Go into Multicurve Function

Set up for testing HA alone

- Preliminary Setup
  - Set HA to User Settings
  - Set Test Equip for Complex Signal
  - Set Test Equip to display OUTPUT, not gain
  - Go into Multicurve Function
Set up for testing HA & FM

SUMMARY

These curves are closely aligned except for the high frequencies at the typical Input levels (1&2).

Additional high frequency info. is often desirable.

Behavioral Verification

ASHA Guidelines-AAA Guidelines

Percent Correct Speech Recognition with and without FM System

Behavioral Testing with FM Systems

- Threshold Testing typically not recommended due to lack of significant information
- Speech Recognition Testing more meaningful
  - Without FM System
  - With FM System
- Test each arrangement in Quiet and in Background Noise if time permits

Setup for Behavioral Testing

1) TEST HA ALONE
2) TEST HA+FM

Speech Recognition Testing

- Select appropriate test with multiple lists
- Set controls to user settings
- Place FM mic on Examiner but turned off
- Place FM receiver on Patient
- Seat Patient in soundbooth at 45 degrees azimuth
Speech Recognition Testing

Test Conditions (AAA, 2007)
- Hearing Aid Alone
  - HA-Quiet (Speech at 50 dB HL)
  - HA-Noise (Add Speech Noise at 50 dB HL)
- Hearing Aid with FM
  - HA+FM-Noise (Keep levels, Turn on FM Mic)
    - If score decreases significantly, then FM gain too low
  - HA+FM-Quiet (Keep levels, Turn off noise)
    - If score increases significantly, then FM gain too low

Determining Significance

Speech Recognition INTerpretation Chart SPRINT
- www.utdallas.edu/~thib
- Convenient Form to compare two speech recognition scores

Verification of CI/FM System Arrangements

1. Check equipment arrangement
   - CI manufacturer
   - FM manufacturer
2. Informal Assessment
   a. Listening check using monitoring headphones
      - Signal from CI microphone
      - Signal from FM microphone
   b. Informal Behavioral Assessment
      - Follow simple directions via CI microphone
      - Follow simple directions via FM microphone
3. Formal Behavioral Assessment
   - Age appropriate speech recognition test
   - Evaluate speech recognition in quiet with CI first, then FM+CI
   - Evaluate speech recognition in noise (0 dB SNR) with CI first, then FM+CI

Verification of CI/FM System Arrangements

SPRINT Chart for 25 word Lists

60% and 80% ARE NOT SIGNIFICANTLY DIFFERENT
60% and 88% ARE SIGNIFICANTLY DIFFERENT
Informal Assessment without the Child

Audiologist performs the Listening Check through monitoring headphones or Radio Shack speaker.

A guide to CI processors that can be evaluated via listening checks is in the “Configurator” section of FM Products at www.phonak.com.

Informal Assessment with the Child

1. Verify that the cochlear implant microphone is receiving the acoustic signal:
   The audiologist will ask the child to follow simple directions or repeat words/phrases.

2. Verify that the cochlear implant is receiving the FM signal:
   The audiologist should step out of the room and have the child follow simple directions or repeat words/phrases.

Formal Behavioral Assessment

Age-appropriate speech recognition test
Same test arrangement as testing HA+FM
Evaluate speech recognition in noise (0 dB SNR) with CI first, then FM+CI
Evaluate speech recognition in quiet with CI first, then FM+CI

Setup for Behavioral Testing

1) TEST CI ALONE

2) TEST CI+FM

Behavioral Results for Students using FM with CI
Thibodeau, Schafer, Overson, Whalen, Sullivan (2005)

Graph showing % Correct for subjects with and without FM in noise.
Behavioral Results for Students using FM with CI
Thibodeau, Schafer, Overson, Whalen, Sullivan (2005)

Behavioral Results TAKE-HOME
Thibodeau, Schafer, Overson, Whalen, Sullivan (2005)

BCI55/50 45.50% (CI alone)
BCIFM55/50 75.25% (CI + FM)

The average improvement when adding the FM system in noise was **29.75%**

BCI55 76.00%
BCIFM55 75.24%

The difference between CI alone and CI+FM in Quiet was minimal.

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### Bilateral/Bimodal Study
Shafier and Thibodeau (2006)

**No FM System Conditions**

<table>
<thead>
<tr>
<th>Bimodal Group</th>
<th>Bilateral Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monaural CI</td>
<td>Monaural CI</td>
</tr>
<tr>
<td>Binaural CI+HA</td>
<td>Binaural CI+FM</td>
</tr>
</tbody>
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<tbody>
<tr>
<td>Monaural with FM CI+FM CI+FM</td>
<td></td>
</tr>
<tr>
<td>Binaural with FM on CI, Side CI+FM HA CI+FM CI+FM</td>
<td></td>
</tr>
<tr>
<td>Binaural with FM on 2nd Side CI CI+FM+FM CI+FM+FM CI+FM+FM</td>
<td></td>
</tr>
<tr>
<td>Binaural with FM on Both CI+FM HA+FM CI+FM+FM CI+FM+FM CI+FM+FM</td>
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</tbody>
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**CHANGE – CHALLENGE**

But with coordinated support of manufacturers, professionals, and research teams, we’ll all overcome these challenges!
SUMMARY

- FM technology is moving to the “head”
- Increasing the functionality of FM systems with addition of Bluetooth that allows connection to cell phones
- Research continues to support the use of FM systems, particularly bilateral systems
- Verification techniques continue to evolve

CONSIDER FM SYSTEMS FOR EVERY EAR OF EVERY CHILD AND VERIFY FM FITTINGS WITH HEARING AIDS AND COCHLEAR IMPLANTS SO THAT…..

REFERENCES


REFERENCES