

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

Linda M Thibodeau, Ph.D.
Professor
University of Texas at Dallas
Callier Center for Communication Disorders

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

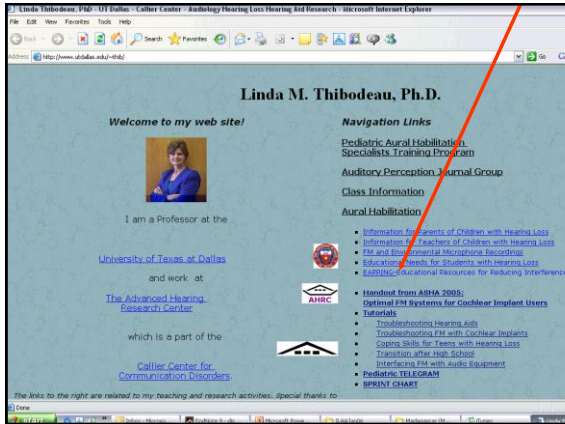
FM Technology-Transmitters and Receivers
Interface with Hearing Aids
Interface with Implants
Verification
[Research](#)

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



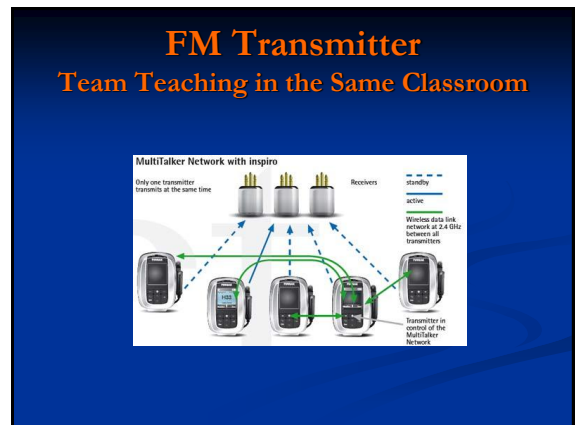
FM Transmitters: Wireless Channel Changeability-WICC

- 1) Direct Frequency Synchronization-DFS
Ex. ML.xi with inspiro
- 2) Automatic Frequency Synchronization-AFS
Ex. ML.xi with Wall Pilot



FM Transmitter Program Capability

<p>Phonak inspiro</p> <p>216-217 MHz</p> <p>Can program Transmitter for selected Channels</p>  <p>Rapid Charge Mute for Cheek Mic</p>	<p>Oticon Amigo</p> <p>216-217 MHz</p> <p>Can use Transmitter to changes settings on FM Receiver</p>  <p>Stores Data Programs FM Adv</p>
---	--



SMART LINK TRANSMITTER



Remote Control, Auto FM, Bluetooth

EASYLINK TRANSMITTER



Similar to SmartLink without the remote control feature
WITHOUT Bluetooth

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

FM Receiver Coupling Options

Basic System-

- Button Earphone
- Headphone
- Soundfield Speaker

Personal System-

- Neckloop
- Direct Audio Input
- Silhouette

*New Term
FM Amplifier
Child comes to school
and removes personal
Hearing aid and uses
Ear level FM system*

FM Systems integrated into BTE Case



FM Receiver

Phonak iLink/MLx S/Amigo

- 216-217 MHz
- Synthesized Channels
- Programmable FM Advantage



iLink

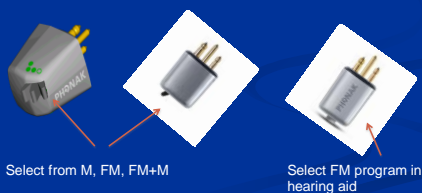
Audio Shoe
FM Receiver



MLxS Amigo

New Smaller Receivers

- Improvements in Pin Orientation



Direct Programmable Audio Interface (DPAI)

- 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 t-coil

Integrated FM Receiver

Phonak iSense
Ear Level FM Receiver
 For Persons with Normal hearing, Mild loss, Auditory Processing Disorder



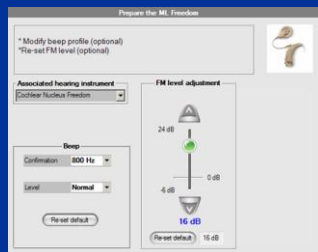
No Microphone
 Programmable Gain
 No Earmold

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
Phonoc Ear FrontRow Pro



Desktop Soundfield Systems
Phonoc Ear Toteable

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

2. Electrical Coupling: Patch Cords to Ear-Level Speech Processors

- Advanced Bionics
 - HiResAuria, CIL, 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



Phonic Ear 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



Sprint with MicroLink CI



Cochlear Accessory Cable + Phonak MicroLink CI with Cable

Pictures from Schafer & Thibodeau (2004)

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

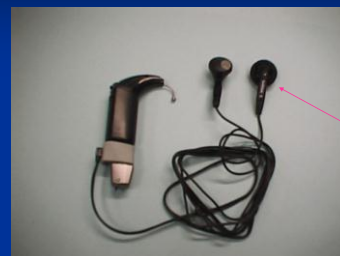
FM receiver build into the battery

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

- BAH is used to for persons with chronic ear infections, congenital loss, and single-sided deafness
- BAH 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



Baha with FM receivers

Validation

Possible components of validation include:

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



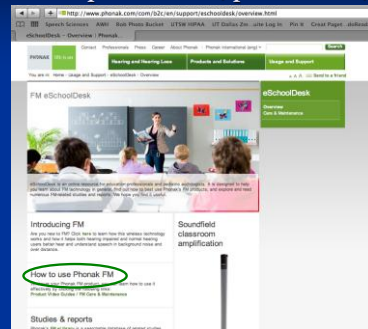
Steps in FM Fitting

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



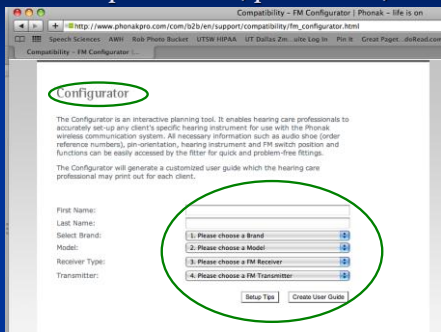
Resources: Phonak eSchool Desk

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
EHA65
- 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
EHA90
- 4) FM&HA: FM in test box-90 dB SPL pure tone signal
EFM/HA90



To Evaluate FM Advantage

- Compare EHA65 with EFMHA65
 - Output curves should match
 - If not within + 3dB adjust FM Advantage setting
- Compare EHA90 with EFMHA90
 - Output curves should match
 - If not within ± 3 dB adjust Max Output setting

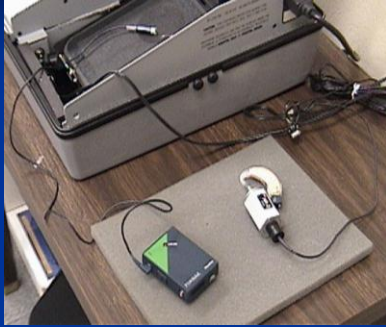
Steps to Verify HA and FM Outputs Preliminary Setup

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



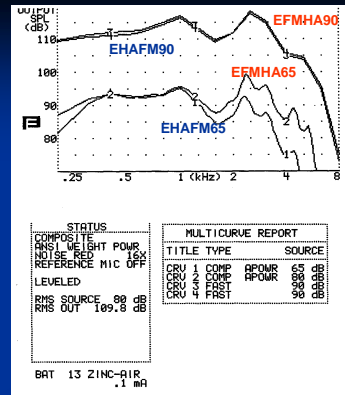
Set up for testing HA & FM



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

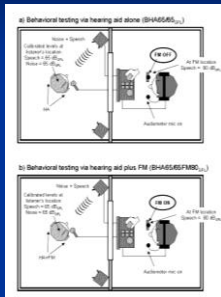
ASHA Guidelines-AAA Guidelines

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

AAA, 2007

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 dBHL)
 - 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

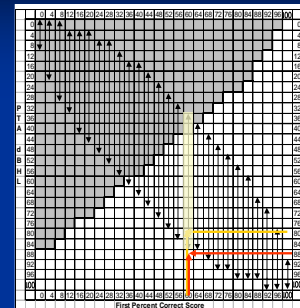
Test Arrangement



Determining Significance

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

SPRINT Chart for 25 word Lists



60% and 80%
ARE **NOT**
SIGNIFICANTLY
DIFFERENT

60% and 88%
ARE
SIGNIFICANTLY
DIFFERENT

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



Verification of CI/FM System Arrangements

4. 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



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 without the Child

Ling Six Sound Test and spondee words
 via CI microphone with monitoring headphones
 via CI microphone plus FM microphone with headphones, or
 via FM microphone with speaker

Audiologist should listen for:
 Distortion in the signal
 Crackling or popping sound

All parts within the FM system should be checked for weak connections by gently moving the parts/cords.

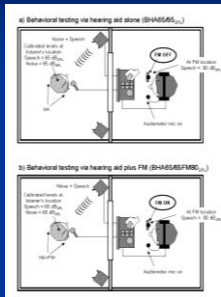
Informal Assessment with the Child

1. Verify that the cochlear implant microphone is receiving the acoustic signal:
 The audiologist will ask the child 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



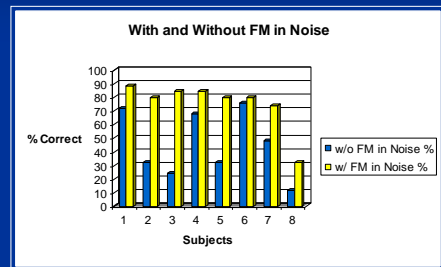
1) TEST CI ALONE

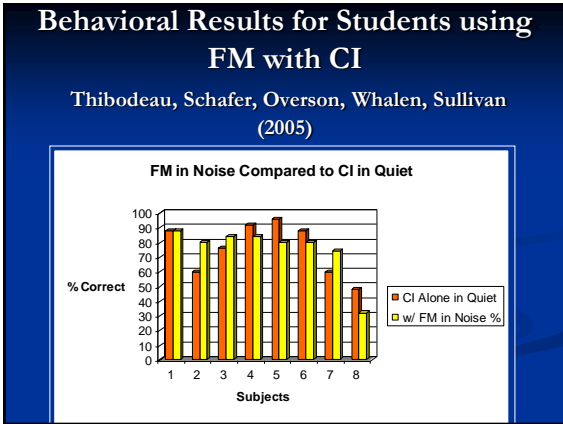
2) TEST CI+FM

AAA, 2007

Behavioral Results for Students using FM with CI

Thibodeau, Schafer, Overson, Whalen, Sullivan (2005)





Behavioral Results TAKE-HOME

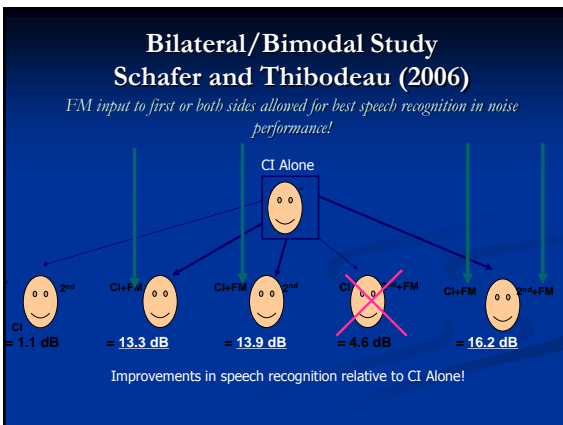
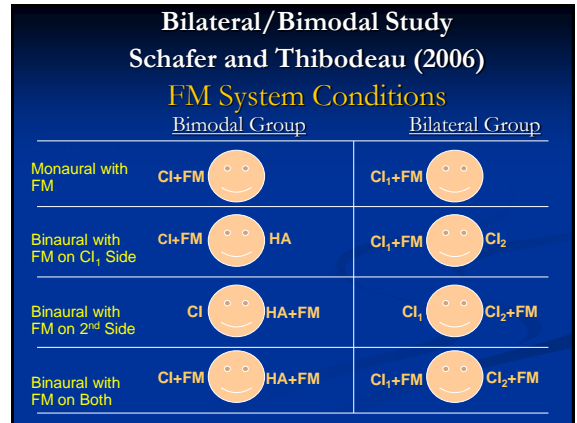
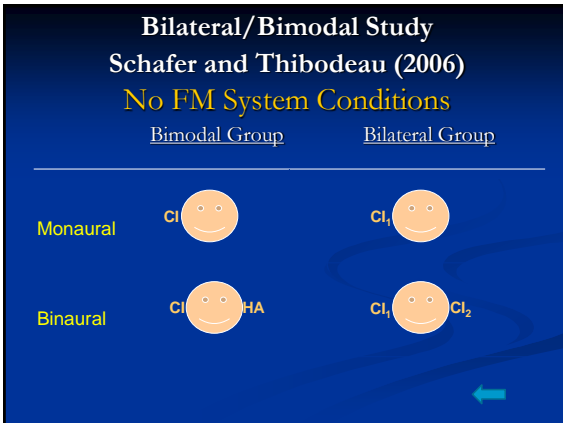
Thibodeau, Schafer, Overson, Whalen, Sullivan (2005)

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.



CHANGE → CHALLENGE

Change always presents challenges?

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.....**

**INSTEAD OF
THIS**



**WE'LL SEE
THIS!**

REFERENCES

- American Speech-Language-Hearing Association. (2002). Guidelines for fitting and monitoring FM Systems. *ASHA Desk Reference*, 2, 151-171.
- Schafer, E.C and Thibodeau, L. (2006) Improving speech recognition in noise of children with cochlear implants; Contributions of binaural input and FM systems. *American J.of Audiology*, 15(2), 114-26.
- Schafer, E. and Thibodeau, L. (2004). Speech Recognition Abilities of Adults Using Cochlear Implants with FM Systems. *J. of the American Academy of Audiology*. 15, 678-691.
- Schafer, E. and Thibodeau, L. (2003). Speech Recognition Performance of Children Using Cochlear Implants and FM Systems. *J.of Educational Audiology*,11, 15-26.

REFERENCES

- Schafer, E., Thibodeau, L., Whalen, H., & Overson, G. (2007). Electroacoustic Evaluation of Frequency-Modulated Receivers Interfaced with Personal Hearing Aids. *Language, Speech, Hearing Services in the Schools*. 38, 1-12
- Thibodeau, L., Fortune, T., and Kring, L. (2006). Comparison of WDRC and ADRO Processing when Combined with an FM System. Poster presented at the American Academy of Audiology, Minneapolis, MN.
- Thibodeau, L., Schafer, E., Overson, G., Whalen, H., and Sullivan, J. (2005) Clinical Evaluation of the Benefits provided by FM Systems directly connected to Cochlear Implants 10th Symposium on Cochlear Implants in Children. Dallas, TX.