American Academy of Audiology

Clinical Practice Guidelines

Remote Microphone Hearing Assistance Technologies for Children and Youth from Birth to 21 Years (Includes Supplement A)

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Remote Microphone Hearing Assistance Technologies for Children and Youth from Birth to 21 Years*

Contents

*This document has been prepared by the Academy's Strategic Documents Committee, Hearing Assistance Technology Task Force: Cheryl DeConde Johnson, EdD, Chair; Vicki Anderson, AuD, Arthur Boothroyd, PhD, Leisha Eiten, MA, Sandra Abbott Gabbard, PhD, Dawna Lewis, PhD, Linda Thibodeau, PhD.

INTRODUCTION

This document was prepared by the American Academy of Audiology Task Force on Guidelines for Remote Microphone Hearing Assistance Technology (HAT). HAT includes a variety of assistive hearing devices. However for the purposes of this document, HAT will only refer to hearing assistance technology that utilizes a remote microphone. Specific statements and recommendations are based on evidence from peer-reviewed and non-peer-reviewed literature, and on consensus practice. This guideline addresses eligibility for, implementation of, and validation of remote microphone HAT for children and youth who have special acoustic and listening needs resulting from deficits of hearing, language, processing, attention, or learning, or who are learning through a second language. The document is designed to address the general provision of remote microphone HAT in Sections 1-9. Supplements contain the specific procedures for fitting and verification for ear-level frequency-modulation (FM), sound field and desktop systems, and induction loop systems. Supplement A addresses ear-level FM, Supplement B addresses classroom audio distribution systems, and Supplement C (under development) will address induction loop system fitting and verification procedures.

1.1. Need for a Guideline Relating to Remote Microphone HAT

Effective listening is compromised by the combined effects of distance, noise, and reverberation[1–13]. The negative consequences of these variables apply to any listener. They are exacerbated, however, by talker-, language-, and listener-dependent factors. Talker-dependent factors include such things as effort, spectrum, rate, articulation, accent, and orientation relative to the listener[14–19]. Language-dependent factors include such things as vocabulary, grammatical complexity, idea complexity, language context, and physical context[20, 21]. Listener-dependent factors include such things as chronological and developmental age, hearing ability, cognitive status, language knowledge, language competence, attention abilities, auditory processing skills, and first language[6, 22–35]. For the developing child, optimal learning and communication require clear speech, developmentally-appropriate language, and received speech levels that are at least 20 dB above those of interfering noise and reverberation[2, 36]. This last requirement is the concern of these guidelines.

Real-world environments, however, typically fall short of this ideal[37–40]. While the normally developing child may be able to cope with a sub-optimal acoustic environment, others may not. Children/youth with deficits of hearing, language, auditory processing, attention, or learning, and for children/youth listening in a non-native language, a poor acoustic environment adds an unacceptable burden, with significant negative effects on learning and development[25, 26, 28, 30, 31, 33, 34, 35, 41–45]. Fortunately, there are technological solutions to the problems created by distance, noise and reverberation[23, 46–64].

The solutions fall under the heading of remote microphone HAT and are conceptually simple. A microphone is placed close to the talker's mouth where the decibel level of the acoustic speech signal is well above that of interfering noise and reverberation. The resulting high quality signal is then delivered to the listener[65, 66].

Four basic wireless delivery options are currently available:[58, 67–69]

1. Personal HAT device in which the speech signal is modulated onto a wireless carrier (e.g., frequency-modulation [FM]) to be picked up by a wireless receiver on the listener, retrieved, and passed to a hearing aid or other hearing device.
2. Classroom audio distribution systems (ADS): targeted area, in which the speech signal is sent to one or more strategically positioned loudspeakers.
3. Classroom audio distribution systems (ADS): target area, in which the speech signal is sent to a single loudspeaker placed close to the listener or target group.
4. Induction loop systems in which the speech signal is delivered to the telecoil of the personal hearing aid, cochlear

implant, or other hearing device via a magnetic signal generated by a loop of wire or other inductor.

The second option may provide less benefit to the individual but can enhance listening for all listeners in the room. When appropriate, sound field amplification can be provided for the whole classroom with the addition of personal wireless amplification, or a personal loudspeaker, for the individual with special acoustic needs. At the time of writing, FM amplification is the most common personal wireless system, but other modulation and carrier options, with or without digital coding, are either available or possible. The present document addresses ear-level FM wireless amplification and classroom audio distributions system. A future supplement will be added to describe neckloop induction technology.

Although conceptually simple, remote microphone HAT is not without its challenges and considerable expertise is called for in selection, adjustment, implementation, monitoring, and maintenance. Because of training and experience in the evaluation and management of hearing, and related communication disorders, audiologists with additional training in the specific area of remote microphone HAT are uniquely qualified to provide the necessary expertise[70, 71].

Among the challenges are appropriate audiological and developmental assessment of the child/youth, assessment of the acoustic and learning environment, and determination of the availability of adequate family and professional support. These and other considerations determine need and eligibility and influence decisions about whether, and how, to proceed with implementation. Foremost at this point is the need to consider and balance acoustic and psychosocial factors. A second challenge is the need to set an appropriate balance between gains via the remote wireless microphone and the microphone in the child/youth's personal hearing device. This balance is critical for optimal benefit[72–74]. A third challenge is the training of family members and professionals who will, ultimately, be responsible for effective use, monitoring, and maintenance—especially for younger children. These and other challenges provide the motivation for, and organizational structure of, these guidelines.

1.2. Purpose and Scope of Guidelines

The purpose of these guidelines is to establish recommended practices for the use of remote microphone HAT for children and youth birth to age twenty-one years. Use of remote microphone HAT is regulated in the schools by the Individuals with Disabilities Education Act (IDEA) as updated in 2004[75]. This document will identify considerations for eligibility, selection, and implementation of remote microphone HAT, fitting and verification procedures, orientation and training with the device, validation and monitoring procedures. The reader is referred to the AAA Pediatric Amplification Guidelines[70] for recommendations for hearing aids. Other documents/guidelines referenced in these guidelines include:

Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools [ANSI s12.60-2002][76]

- Acoustic Terminology [ANSI S1.1-1994 (R1999)][77]
- Guidelines for Fitting and Evaluation of FM Systems[78]
- Audiology Clinical Practice Algorithms and Statements[79]
- Pediatric Working Group of the Conference on Amplification for Children with Auditory Deficits[80]
- Regulations for the Individuals with Disabilities Education Act (IDEA) of 2004[75]
- Section 504 of the Rehabilitation Act of 1973[81]
- The Americans with Disabilities Act of 1990[82]

These guidelines are targeted to children and youth and designed to address the listening needs of three groups within this population:

Group 1. Children and youth with hearing loss who are actual or potential hearing aid users;

Group 2. Children and youth with cochlear implants and bone-conduction hearing devices;

Group 3. Children and youth with normal hearing sensitivity who have special listening requirements.

While most of the HAT considerations discussed in this document apply to each of these groups, some parameters are affected by the different hearing conditions. To provide more detailed guidance, audiological considerations and fitting and verification procedures will be addressed separately for each group.

2. REGULATORY CONSIDERATIONS

Several federal regulations contain specific requirements or references pertaining to the use of assistive technology, and remote microphone HAT, specifically. The Individuals with Disabilities Education Act (IDEA) 2004 contains the most specific language describing eligibility, selection, fitting and implementation of assistive technology that is required for children as part of their Individual Family Service Plan (IFSP) or Individual Education Program (IEP) (34CFR300.5-.6). These regulations are contained in Appendix A. Section 504 of the Rehabilitation Act of 1973[81] and the Americans with Disabilities Act[82] pertain to individuals in all settings and provide for accessibility for individuals with disabilities including hearing loss. Any audiologists who are prescribing and fitting remote microphone HAT must be knowledgeable about these federal regulations as well as any state regulations that may pertain to HAT. Individual state regulations contain definitions of hearing loss and eligibility for special education and related services that impact use of remote microphone HAT. In particular, consideration of special types of hearing disorders such as unilateral hearing loss or auditory processing disorders may be quite different in each state. While qualifications for fitting remote microphone HAT are not currently regulated by the FDA, audiologists are the only hearing health care professionals with the appropriate training to fulfill the recommendations of these guidelines relative to fitting HAT (see personnel qualifications in the next section).

3. PERSONNEL QUALIFICATIONS

In alignment with the Pediatric Amplification Guideline[70], the Audiology: Scope of Practice [Revised January 2004][71], and general practice standards for audiologists, the following standards are to be followed for fitting remote microphone HAT.

1. Audiologists are the professionals singularly qualified to select and fit all forms of amplification for children and youth, including personal hearing aids, frequency-modulated (FM) systems, and other HAT. Audiologists also program and manage cochlear implant fittings. Audiologists have a master's and/or doctoral degree in audiology from a regionally-accredited university.
2. Audiologists must meet all state licensure and/or regulatory requirements.
3. Audiologists fitting hearing aids and remote microphone HAT on children and youth should have the expertise and the test equipment necessary to complete all tests for device selection, evaluation, and verification procedures described herein.
4. Audiologists must adhere to procedures consistent with current standards of practice to assess auditory function in

children and youth[79].

5. Audiologists must be knowledgeable about federal and state laws and regulations impacting the identification, intervention, and education of children and youth who are deaf and hard of hearing.

4. EQUIPMENT AND SPACE REQUIREMENTS

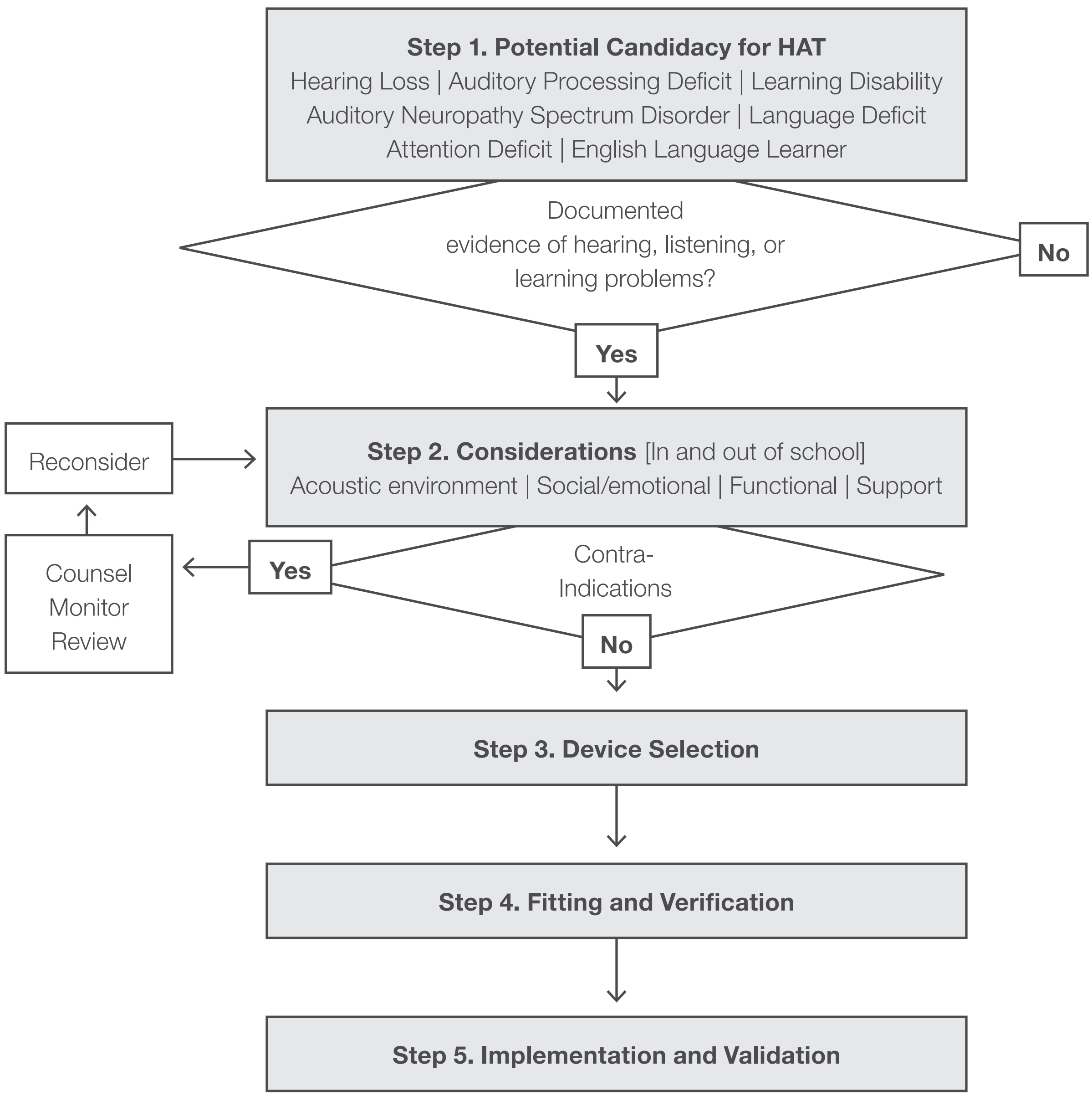
In order for audiologists to comply with the requirements of IDEA regarding the determination of the need for remote microphone HAT as well as selecting, fitting, and evaluating the effectiveness of HAT for children/youth, certain equipment and space provisions must be met. There also needs to be sufficient time in the audiologist's schedule to perform these procedures to effectively manage the implementation of HAT. Equipment and HAT budgets should be structured to consider planned replacement so that unexpected expenses are not incurred for audiological equipment as well as to insure that HAT devices reflect recent technological advancements that enhance its functionality for students.

1. The following equipment and materials are necessary for appropriate assessment, selection, fitting, verification, and validation of remote microphone HAT.
   - Sound booth with diagnostic 2-channel audiometer and sound field capabilities
   - Sound level meter
   - Materials for measuring or estimating reverberation time
   - Otoscope
   - Electroacoustic Analysis equipment
   - Real Ear Measurement equipment
   - Battery testers, stethoscopes, hearing aid checking devices, and cochlear implant monitoring earphones
   - Visual aids and materials for training and classroom presentations
   - Age-appropriate test materials for selection, verification, and validation
   - Back-up HAT devices/accessories
2. Space for equipment should be ventilated for cooling, relatively dust-free, and away from noise sources and excessive vibration. Sufficient space is needed to accommodate the examiner, the child/youth being assessed, and the necessary equipment, including sound field testing, to conduct all measurements.
3. Procedures for checking and servicing HAT devices and storage for equipment during school breaks should be developed as part of the audiologist's HAT implementation and management plan. Performance data on HAT devices should be maintained in order to track when device performance warrants replacement.

5. REMOTE MICROPHONE HAT CANDIDACY, IMPLEMENTATION AND DEVICE SELECTION CONSIDERATIONS

Figure 1 illustrates the steps required in the remote microphone HAT candidacy, selection, fitting and implementation process. These steps are:

- Step 1—Potential candidacy for remote microphone HAT
- Step 2—Implementation considerations for remote microphone HAT



- Step 3—Device selection considerations

- Step 4—Fitting and verification
- Step 5—Implementation and validation including orientation, training and device monitoring

HAT Implementation Worksheets are located in Appendix A. There are worksheets for both in-school and out-of-school HAT use. The out-of-school practices are suggested for young children as well as other non-school environments where HAT use is desired and advantageous. These worksheets may be used by the audiologist as a guide through the steps in the process.

Figure 1. Remote Microphone HAT candidacy, device selection, and implementation process.

5.1. Potential Candidacy for Remote Microphone HAT (Step 1)

Any child or youth with documented hearing, listening, and/or learning problems may benefit from enhancement of his/her teachers' and classmates' voices for classroom instruction and discourse[47, 83]. These children and youth have conditions such as hearing loss and other auditory deficits, underdeveloped auditory systems, language delays and disorders, limited knowledge of English, as well as attention problems that compromise their ability to hear and listen in adverse acoustic situations. One strategy or accommodation to minimize the difficulties experienced by children/youth who have listening or learning problems is the use of remote microphone HAT. These amplification systems counteract the effects of background noise, distance from the talker, and high reverberation levels all of which are common acoustic problems in classrooms[6, 38, 76, 84, 85]. Children and youth who may be candidates for remote microphone HAT include those with:

- Hearing loss
- Auditory processing deficits
- Learning disabilities
- Auditory neuropathy spectrum disorder
- Language delay/disorder
- Attention deficits
- English as a second language

5.2. Implementation Considerations for Remote Microphone HAT (Step 2)

There are several considerations that impact the decision of whether or not to implement the use of HAT for each child/youth with listening or learning problems determined to be a candidate. The following list of considerations, while not exhaustive, specifies areas that commonly affect this decision including in-school and out-of-school issues. As these areas are discussed, any issues that require additional attention should be noted and incorporated into the implementation plan. If there are contraindications for fitting remote microphone HAT that are identified, the audiologist, school and family members should consider counseling to address the problem. The audiologist should also periodically monitor and review the situation and reconsider HAT use when appropriate.

Area	Decision Considerations for Implementation of Remote Microphone HAT
Acoustical environment	
ANSI standards for noise and reverberation[76] Transient noise	Classroom, home and other communication environments should be sufficiently quiet and free from reverberation to permit close 1:1 and small group conversation at comfortable talking levels and with listening ease; HAT may be required to reduce or eliminate noise and/or distance factors to make communication more accessible.
Social-emotional	
Motivation Student & teachers Child & family members	Motivation of the child/youth, teacher, and family members will determine success of HAT fitting and implementation; motivators & reinforcers may be needed to encourage HAT use[86].
Attention and fatigue Listening/looking	Inattention & fatigue provide evidence for HAT candidacy; the increased speech-to-noise HAT benefit may improve focus and reduce listening strain[87, 88].
Self-image	The self-image of the child/youth, teacher, and family members may affect HAT success. Child, family member and/or teacher may need counseling or assistance to encourage positive acceptance of wearing and using additional technology[89].
Self-advocacy	Good self-advocacy skills will increase the child/youth's likelihood of success with HAT. If self-advocacy skills are low, teaching self-advocacy skills should be included in goals on the IFSP/IEP[90]. Skills should include self-monitoring of HAT and how to report suspected malfunction.
Social acceptance	A child/youth who is well-accepted by his/her peers and who has made one or more friends in school may be more likely to tolerate and embrace the benefits that HAT can offer[91].
Classroom culture	A classroom which celebrates diversity, embraces technology and alternative learning opportunities, and values the unique gifts of each individual will more quickly and efficiently adapt to and support the use of HAT. Where these are lacking, extensive classroom inservice activities may be needed and should be included in the IFSP/IEP goals[92, 93].
Family support	Parents should receive inservice training regarding the benefits and limitations of FM technology, including suggestions for how to encourage and support their child/youth in HAT use. Family-to-family support should be included and documented in the IFSP/IEP[94, 95].
Functional	
Age: chronological/developmental	Age of implementation of HAT will be impacted by mobility and safety concerns. Once an infant/child spends time at distances away from the talker or in noisy situations (e.g., car, restaurant), HAT use should be considered[75].

Academic	Academic considerations include the learning environment as well as the child/youth's language and academic skill level. When considering the benefits of HAT, consider its impact on access to the curriculum as well as associated skills such as ease of communication by improving attention and decreasing response time and the potential for reducing stress[45]. Further, use of HAT outside of school may be necessary to support language and learning goals in the child/youth's IEP.
Communication skills	Consider the child/youth's communication skills with and without HAT, including ease of communication and the potential for enhancing communication access with HAT.
Home communication environment	Understanding communication access needs in the home environment is important to assist family members in determining situations in which HAT should be implemented as well as situations where HAT use would be inappropriate. Car, meals, TV/movies/theater, and recreation all present opportunities for listening and communication that can be enhanced by appropriate use of HAT.
Support	
Awareness	Awareness of the child/youth's communication needs and the potential benefits of HAT are important for parents/caregivers and educational personnel.
External acceptance	Willingness of family members and/or educational personnel to utilize the equipment improves the likelihood of successful implementation of HAT. In addition, administrative support is necessary for the use, updating, and maintenance of equipment in academic settings.
Ability to use and manage technology	Successful implementation requires that the family, with professional support, is capable of understanding and managing the technology. A qualified person should be identified as responsible for monitoring and maintaining the equipment. In addition, the user's physical and developmental status must be addressed.
Financial resources	For out-of-school plans, the family should be aware of HAT costs and available funding sources for purchase. Final implementation decisions may depend on the amount of available funding (e.g., monaural vs. binaural FM). For in-school plans, appropriate financial resources must be allocated for purchase and maintenance.
ADA obligations	For out-of-school plans, families should be made aware of current federal regulations regarding HAT as well as services and equipment in their community to provide communication access. Families and children/youth that are able to self-advocate for access needs increase the likelihood of successful HAT implementation.

5.3. Device Selection Considerations (Step 3)

Selection of a HAT device involves analysis of audiological, developmental, listening environment, and technology issues as well as consideration of funding options. Listening environments for in-school and out-of-school are addressed.

5.3.1. Audiological Considerations

Audiological procedures continue to evolve and those that contribute to differential diagnosis (e.g., validated, age-appropriate, and interpretable) should be applied to each situation. While anecdotal reports by teachers and parents may also be used, audiologists are encouraged to use tools that provide quantifiable data that can supply information regarding performance without the use of the HAT. These audiological tools may include measures of self-assessment (e.g., Classroom Participation Questionnaire, CPQ)[96] , observation questionnaires (e.g., Screening Instrument for Targeting Educational Risk, SIFTER)[97] , and speech perception in noise tasks (e.g., Hearing in Noise Test for Children, HINT-C)[98]. A comprehensive evaluation utilizing multiple assessments provides a variety of perspectives of the child's hearing and listening performance.

The following default arrangements (i.e., the fitting arrangement of choice) are recommended for each HAT candidate group unless the situation indicates otherwise. The fitting should be accomplished with the fewest number of connections. There are three methods of directly connecting the receiver to the device: *integrated* (the receiver is built-into the personal device), *dedicated* (the receiver is compatible with one case design), *universal* (the receiver works with multiple devices depending on the interface between the device and the receiver, i.e., a 3-pin polarized connection).

Group		Default Fitting Arrangement
Group 1	Children and youth with hearing loss who are actual or potential hearing aid users	Bilateral ear-level wireless technology
Group 2	Children and youth with cochlear implants and bone-conduction hearing devices	Headband-anchored: Ear-level wireless technology Bone-anchored: There is not a default HAT arrangement*
Group 3	Children and youth with normal hearing sensitivity who have special listening requirements	There is not a default HAT arrangement for this population.

Style and fitting considerations are based on hearing status, degree, configuration and stability of loss, current use of hearing technology, and any other special situations that are present.

Group 1.	Hearing Status/Type	Possible Contraindications to Default Fitting	Alternatives
Children and Youth with hearing loss who are actual or potential hearing aid users	Conductive/sensorineural/mixed	Ear drainage External Otitis	1. Alternate amplification use between ears (fit with caution relative to gain setting and monitor fitting frequently). 2. Targeted area ADS. 3. Whole classroom ADS.

	Unilateral or asymmetric loss	Clinically or functionally significant threshold and/or speech perception differences between ears	1. Fit ear-level FM-only to normal ear. 2. Fit poorer ear if functional benefit can be demonstrated. 3. Fit unilaterally to better ear. 4. Targeted area ADS. 5. Whole classroom ADS.
	Auditory neuropathy spectrum disorder	Normal peripheral hearing Variable, uncertain, and or near normal behavioral responses	1. Fit ear-level FM-only receiver (fit with caution relative to gain setting and monitor fitting frequently). 2. Targeted area ADS. 3. Whole classroom ADS.
Group 2. Children and youth with cochlear implants or bone-conduction hearing devices	**Type (CI)**	**Possible Contraindications to Default Fitting**	**Alternatives**
	Unilateral/bilateral Bimodal (HA/CI) Hybrid (HA/CI in same ear)	Inability to reliably confirm integrity of one or both connections. Inability to achieve FM gain setting within electrical dynamic range of cochlear implant.	1. Fit unilaterally (requires evaluation to determine the best arrangement). 2. Targeted area ADS. 3. Whole classroom ADS.
	Type (Bone Conduction)	**Possible Contraindications to Default Fitting**	**HAT Options**
	Headband-anchored Bone-Anchored	**No default**	1. Fit non-occluding ear-level FM-only receiver (fit with caution relative to gain setting and monitor fitting frequently). 2. Target area ADS. Classroom ADS

Group 3.	Type	Possible Contraindications to Default Fitting	HAT Options
Children and youth with normal hearing sensitivity who have special listening requirements	Auditory processing deficits Learning disabilities Language deficits Attention deficits English language learners	No default	1. Fit non-occluding ear-level FM-only receiver (fit with caution relative to gain setting and monitor fitting frequently). 2. Targeted area ADS. 3. Whole classroom ADS.

*While children with bone-anchored hearing devices would benefit from enhanced SNRs, there is no research to support a specific arrangement.

5.3.2. Developmental Considerations

Area	Selection and Implementation Considerations
Age	
Chronological Developmental	Age will affect many decisions, including the style of receiver, wearer acceptance, where and in which activities the HAT will be used (e.g., IDEA makes provision for HAT use in the “natural environment” which may be interpreted as home use), the type and amount of inservice training which will be needed, the amount of monitoring needed, and by whom. Infants and toddlers may require special HAT style considerations, including size and weight of BTE aid with FM shoe and receiver, tamper-proofing, etc.
Academic Performance	
At or above grade level Below grade level	The degree of academic delay may influence the type of HAT considered, (e.g., the better the student’s academic classroom performance, the more flexible the choice of device options).

Additional Problems	
Attention Hyperactivity Sensory integration Behavior Cognition Mobility Auditory processing Learning Vision Fine motor	Multiple disabilities in addition to HL may further support HAT candidacy and may also require special considerations. Children/youth with low cognition may require additional support and monitoring, and device style considerations may apply. Children/youth with low vision may also be considered a high priority for HAT devices, and special style considerations may apply (e.g., devices with tactually identifiable components and switches, etc.). Other deficits in addition to HL, including sensory integration and auditory processing, may impact decisions about speech-to-noise requirements, device style, or inservice training needs. Children/youth and/or teachers/adults with limited mobility or dexterity problems will need special device style considerations, additional support, assistance, and monitoring.

5.3.3. Listening Environment Considerations – School

Area	Selection and Implementation Considerations
School Learning Environment	
Lecture Discussion One on one Team teaching Single group Multiple groups	The amount and type of exposure to challenging listening environments during academically focused interaction may influence the type and duration of use of HAT. Each environment will need to be assessed with consideration for the location of the teacher in relation to the student, the amount of student-to-student interaction, and any change in physical environment during the academic instruction.
School Access Needs	
Teachers Peers Single talker Multiple talkers Structured learning Unstructured learning Technology (computer, tv)	Student's access will need to be evaluated to accommodate the specific types of sound input required. The number of teachers interacting with the student as well as potential student-to-student interaction and possible external sound inputs (e.g., computers or TV) will influence the number of transmitters and types of microphones necessary to provide adequate access. Appropriate microphone set-up will be dependent upon the specific needs for the environment but may include individual transmitters working together with a pass around or conference microphone.

School Acoustic Needs	
Signal sources (intensity & spectrum) Noise sources (spectrum & time) Reverberation Room size and shape Student position	The acoustical quality of the learning environment will influence HAT candidacy and technology. An acoustic environment which compromises the signal-to-noise ratio, environmental influences, room size or shape, or student position will support HAT candidacy for the student. Classroom audio distribution systems may not provide optimal signal quality in environments with compromised room acoustics.
Current HAT in Use at School	
Teacher support Peer support	Appropriate teacher support is critically important to successful HAT use in the classroom. Good support can foster consistent and appropriate use of HAT technology. Peer support is also a critical component to successful use from both social emotional and technology competency perspectives.
Other School Locations	
Auditorium/theater Therapy areas Gymnasium Cafeteria Extra-curricular activity sites Library Specials: music, computer, resource	The learning environment which requires accessibility for the student should include all of the locations the student travels in the course of his/her school experience. Each environment may have its own technology needs and should be evaluated for each student.

5.3.4. Listening Environment Considerations – Home and Community

Area	Selection and Implementation Considerations
Home Activity Needs	
Meals Play—structured activities (e.g., reading, table games) Play—unstructured (e.g., single/multiple groups)	HAT candidacy for specific home environments will be influenced by the type of activities in the listener's routine that result in a compromised signal from the sound source. Evaluation of the use of HAT technology during specific activities can help identify needs and promote successful implementation.

Home Access Needs	
Family, friends, peers Single/multiple talkers Structured activities Unstructured activities Audio visual technology (tv, dvd, stereo, computer) Electromagnetic and Bluetooth technology	The listener's access will need to be evaluated to accommodate the specific types of sound input required. The number of individuals interacting with the listener as well as possible external sound inputs (e.g., computers or TV) will influence the types of microphones and receivers necessary to provide adequate access.
Home Acoustic Needs	
Signal sources (intensity & spectrum) Noise sources (spectrum & time) Reverberation Room size and shape Child position Wireless interference	The acoustical quality of the home environment will influence HAT candidacy and technology. An acoustic environment which compromises the signal-to-noise ratio, environmental influences, room size or shape, or listener position will support HAT candidacy for the listener in those environments.
Other Locations	
Recreation Church Community Therapy	Other locations in the listener's environment may become accessible with the use of HAT technology. The listener's environments should be explored to identify where communication could be enhanced with the use of HAT technology.

5.3.5. Technology Considerations

Area	Selection and Implementation Considerations
Technology Considerations	
Convenience Wearability Reliability Maintenance Ease of monitoring Manufacturer/dealer support Compatibility with existing amplification Compatibility with computers, phones, and other devices Signal interference Multiple FM frequencies Bluetooth compatibility Electromagnetic compatibility	Multiple technological considerations need to be addressed when selecting and implementing HAT devices. Technology decisions are viewed within the broader context of access in all of the child/youth's communication environments.

5.3.6. Funding Considerations

HAT is considered assistive technology under IDEA[75]. Therefore when HAT is recommended in the IEP, it must be provided by the school system as part of the requirements of IDEA under assistive technology (34CFR300.5) and assistive technology services (34CFR300.6). HAT recommended as part of the IFSP should be provided through the state's Part C funding entity. In many states, Part C may be a last resort funding source. When HAT is recommended for children/youth that are on 504 plans, the child's local school is responsible to provide the device under the accessibility requirements of Section 504[81] (general education, not special education). ADA[82] also requires that school districts purchase HAT when needed for general community accessibility of school programs and activities. In situations where individual funding needs to be secured, options include the family's insurance (private or public), state public health programs, local service organizations (e.g., Sertoma, Lions, Optimist), and other foundations. State agencies such as the school for the deaf, department of education, department of health, or department of rehabilitation services may also operate HAT loaner programs.

† At this time there is not definitive evidence to support an advantage of bilateral over monaural FM fittings or boom microphone versus lapel microphone versus use of other microphone location (i.e., conference microphone)[61, 99-101]. Further research is needed in this area.

‡ Ibid

5.3.7. Device Determination

Once all of the considerations have been addressed, an appropriate device is selected for the student.

The device includes:

- receiver
- transmitter/microphone
- accessories

Refer to the appropriate Supplement for further information regarding device features (e.g., Supplement A, SA 1.1., SA 1.2.).

6. FITTING AND VERIFICATION PROCEDURES (STEP 4)

Once an appropriate remote microphone HAT has been selected, the performance of the system requires careful verification before fitting on a child/youth. The specific procedures implemented for verification will vary depending on the listener group and the type of remote microphone system selected. Testing should include a combination of electroacoustic, real-ear and behavioral measures as appropriate. Detailed verification procedures are available in Supplement A. Specific procedures are included for verification of: 1) Remote microphone ear-level FM with hearing aids; 2) Remote microphone FM with cochlear implants and bone-conduction hearing devices; and 3) Ear-level FM only. Terms related to fitting and verification are defined in the glossary found in Appendix C.

Fitting Goals

These goals represent recommended practice unless individual testing indicates otherwise.

- Audibility and Intelligibility
  - Speech recognition that is commensurate with performance in ideal listening conditions.
  - Full audibility of self and others.
  - Reduced effects of distance, noise and reverberation.
- Preferred practice to accomplish full audibility
  - Consistent signal from the talker regardless of head movement†.
  - Technology that will be worn consistently by the individual, parent and/or teacher.
  - Technology that will provide full audibility according to listener group:
    - Group 1. Children and youth with hearing loss who are actual or potential hearing aid users: Bilateral ear-level wireless technology and fewest equipment adjustments‡.
    - Group 2. Children and youth with cochlear implants or bone-conduction hearing devices: Bilateral wireless technology.

- Group 3. Children and youth with normal hearing sensitivity who have special listening requirements: There is not a default HAT arrangement for this population.

7. IMPLEMENTATION AND VALIDATION PROCEDURES (STEP 5)

7.1 Orientation, Training and Usage Plan

Prior to completing the fitting process for HAT, a plan should be developed that details the orientation, training and follow-up support that children/youth, community/school staff, and family members/caregivers will receive as well as a plan for when the device will be used. This plan should include the content of the training as well as determination of who will provide the training, the necessary qualifications of the trainer, whether IFSP/IEP goals are necessary for the child/youth to attain the HAT goals, and what parent/caregiver training is needed for the child/youth to attain HAT goals (some parents may require specific parent training and counseling services [IDEA 34CFR300.34[c]).

7.1.1. Orientation and Training

Orientation and Training Topics for Children/Youth

- Implications of hearing loss
- Basic function of device
- Appropriate use of device and features
- Expectations: benefits and limitations of the device including when to use and when not to use
- Care and Maintenance
- Basic troubleshooting and reporting of a suspected malfunction
- Self-monitoring of function
- Self-advocacy

Training Topics for Parents/Caregivers/Teachers

- Basic implications of hearing loss
- Basic function of device
- Appropriate use of device and features
- Expectations: benefits and limitations of the device including when to use and when not to use
- Listening check & basic troubleshooting
- Reporting of a suspected malfunction

- Advocacy
- Classroom orientation to HAT

7.1.2. Usage Plan

- full time
- part time
  - specific environments (e.g., auditorium, car)
  - specific activities (e.g., assemblies, therapy, classroom discussion, organized physical activities, family outings)

7.2. Validation Procedures

As with hearing aids and implanted devices, validation of amplified auditory function is a demonstration of the benefits and limitations of the recommended HAT device. Validation is an ongoing process that begins immediately after fitting and verification and is designed to ensure that the child/youth is receiving optimal speech input from others and that his or her own speech is adequately perceived[80]. Validation procedures may consist of objective or subjective measures and should occur in, and reflect, the typical listening environments experienced by the individual. IDEA requires that the selection and use of assistive technology include a functional evaluation of the child/youth in their customary environment. Typical tools for validation include self-assessments, observation questionnaires completed by parents and teachers, and functional evaluations conducted with the child/youth in their learning environment.

> Paramount to the validation process is determining that the evidence demonstrates that the recommended HAT achieves the child/youth's communication access fitting goals by 1) providing full audibility and intelligibility of speech that is commensurate with their best speech recognition performance in ideal listening conditions, 2) maintaining full audibility of self and others, and 3) reducing the deleterious effects of distance, noise, and reverberation.

There are several tools, including those listed below, that are helpful for validating HAT. Some are specifically designed to provide evidence of HAT benefit while others target developmental components of more general behaviors which can be affected by HAT use. Most, however, do not have published psychometric data at this time and, therefore, should be used cautiously. Appendix D contains a descriptive list of common functional outcome measures used in pediatric audiology.

Tool	Developmental	HAT Validation
Self-Assessment		
Listening Inventory for Education LIFE [102]		X
Classroom Participation/Ease of Communication (Classroom Participation Questionnaire-CPQ)[96]	X	
Observation Questionnaire		
Early Listening Function (ELF)[103]		X
Children's Home Inventory of Listening Difficulties (CHILD)[104]		X
FM Listening Evaluation for Children[105]		X

Listening Inventory for Education (LIFE)[102]		X
Screening Instrument for Targeting Educational Risk (SIFTER)[97], Preschool SIFTER[107], Secondary SIFTER[107]	X	
Meaningful Auditory Integration Scale (MAIS)[108], Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS)[109]	X	
Functional Auditory Performance Indicators (FAPI)[110]	X	
Children's Auditory Processing Scale (CHAPS)[111]	X	
Evaluation		
Functional Listening Evaluation (FLE)[112]		X
Ling Six Sound Test[113]	X	X

While anecdotal reports by teachers and parents may also be used, audiologists are encouraged to use tools that provide quantifiable data that can supply baseline data (without the use of the HAT) and demonstrate achievement of the fitting goals with the HAT.

Behavioral audiometric procedures such as sound field aided speech recognition can provide useful confirmation of HAT performance. These measures are also considered part of the verification process and are described in Supplement A, Fitting and Verification Procedures for Ear-level FM.

Once the HAT has been determined and validated, it should be identified in the HAT Implementation Plan and when appropriate, included in the child/youth's IEP. The IEP recommendation should provide justification as well as describe the specific HAT features that are required, rather than a brand/model, to accommodate the changing listening needs that result from various classroom and school placements. The child/youth's IEP should also include goals for independent HAT use and self-advocacy when appropriate.

7.3. Monitoring Procedures

Any child/youth that uses HAT must have a monitoring plan in place to ensure that the recommended HAT device is functioning properly. Repairs should be completed in a timely manner and a loaner or acceptable substitute should be provided in the interim.

HAT that is required for students as part of their special education services must be designated in the Individual Education Program (IEP). In addition, IDEA[75] requires that schools must monitor the performance of amplification devices worn by children/youth to assure that they are functioning properly. Appropriate equipment to monitor performance of HAT (e.g., battery testers, stethoscope) must be available. To accomplish this requirement a monitoring plan should document the following information for each student:

- Person who will monitor;
- Location of monitoring;
- When and how often HAT will be monitored;

Procedure used to monitor [e.g., Ling 6 sounds[113] (oo, ah, ee, sh, s, mm)];

- Procedure to follow when HAT malfunctions

In addition to monitoring the function of HAT devices, performance with amplification instruments should also be observed. Audiologists should be mindful of whether the children/youth are

- Meeting their personal auditory/listening goals;
- Achieving communication access with their teachers and school staff;
- Achieving communication access with their peers.

If, at a later date, a student refuses the device or a decision is made that HAT is no longer appropriate, the IEP team must meet to remove the recommendation for the device from the student's IEP.

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9. APPENDICES

Pertinent Regulations from the Individuals with Disabilities Education Act (IDEA) (2004)75

PART B RELATED SERVICES 34CFR300.34(b)

Exception; services that apply to children with surgically implanted devices, including cochlear implants.

(1) Related services do not include a medical device that is surgically implanted, the optimization of that device's functioning (e.g., mapping), maintenance of that device, or the replacement of that device.

(2) Nothing in paragraph (b)(1) of this section—

(i) Limits the right of a child with a surgically implanted device (e.g., cochlear implant) to receive related services (as listed in paragraph (a) of this section) that are determined by the IEP Team to be necessary for the child to receive FAPE.

(ii) Limits the responsibility of a public agency to appropriately monitor and maintain medical devices that are needed to maintain the health and safety of the child, including breathing, nutrition, or operation of other bodily functions, while the child is transported to and from school or is at school; or

(iii) Prevents the routine checking of an external component of a surgically-implanted device to make sure it is functioning properly, as required in §300.113(b).

PART B - DEFINITION OF AUDIOLOGY 34CFR300.34(c)(1)

Audiology includes:

(i) Identification of children with hearing loss;

(ii) Determination of the range, nature, and degree of hearing loss, including referral for medical or other professional attention for the habilitation of hearing;

(iii) Provision of habilitation activities, such as language habilitation, auditory training, speech reading, (lipreading), hearing evaluation, and speech conservation;

(iv) Creation and administration of programs for prevention of hearing loss;

(v) Counseling and guidance of children, parents, and teachers regarding hearing loss; and

(vi) Determination of children's needs for group and individual amplification, selecting and fitting an appropriate aid, and evaluating the effectiveness of amplification.

PART C - DEFINITION OF AUDIOLOGY 34CFR303.1 (from 2004 proposed Part C IDEA regulations)

Audiology services includes-

(i) Identification of children with auditory impairments, using at risk criteria and appropriate audiological screening techniques;

(ii) Determination of the range, nature, and degree of hearing loss and communication functions, by use of audiologic evaluation procedures;

(iii) Referral for medical and other services necessary for the habilitation or rehabilitation of an infant or toddler with a disability who has an auditory impairment;

(iv) Provision of auditory training, aural rehabilitation, speech reading and listening devices, orientation and training, and other services;

(v) Provision of services for the prevention of hearing loss; and

(vi) Determination of the child's need for individual amplification, including selecting, fitting, and dispensing of appropriate listening and vibrotactile devices, and evaluating the effectiveness of those devices.

PART B ASSISTIVE TECHNOLOGY 300.105(a)(2)

On a case-by-case basis, the use of school-purchased assistive technology devices in a child's home or in other settings is required if the child's IEP Team determines that the child needs access to those devices in order to receive FAPE.

PART B ROUTINE CHECKING OF HEARING AIDS AND EXTERNAL COMPONENTS OF SURGICALLY IMPLANTED MEDICAL DEVICES 34CFR300.113

(a) *Hearing aids.* Each public agency must ensure that hearing aids worn in school by children with hearing impairments, including deafness, are functioning properly.

(b) *External components of surgically implanted medical devices.*

(1) Subject to paragraph (b)(2) of this section, each public agency must ensure that the external components of surgically implanted medical devices are functioning properly.

(2) For a child with a surgically implanted medical device who is receiving special education and related services under this part, a public agency is not responsible for the post-surgical maintenance, programming, or replacement of the medical device that has been surgically implanted (or of an external component of the surgically implanted medical device).

ASSISTIVE TECHNOLOGY; PART B 34CFR300.5-.6 & C: 34CFR303.12

Assistive technology device means any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of children with disabilities. The term does not include a medical device that is surgically implanted, or the replacement of such device.

Assistive technology service means any service that directly assists a child with a disability in the selection, acquisition, or use of an assistive technology device. The term includes-

(a) The evaluation of the needs of a child with a disability, including a functional evaluation of the child in the child's customary environment;

(b) Purchasing, leasing, or otherwise providing for the acquisition of assistive technology devices by children with disabilities;

(c) Selecting, designing, fitting, customizing, adapting, applying, maintaining, repairing, or replacing assistive technology devices;

(d) Coordinating and using other therapies, interventions, or services with assistive technology devices, such as those associated with existing education and rehabilitation plans and programs;

(e) Training or technical assistance for a child with a disability or, if appropriate, that child's family; and

(f) Training or technical assistance for professionals (including individuals providing education or rehabilitation services), employers, or other individuals who provide services to, employ, or are otherwise substantially involved in the major life functions of children with disabilities.

Remote Microphone HAT Implementation Worksheet

B.1. In-School Form

Name ____ **Date** _________

The *HAT Implementation Worksheet* is a five step process to document eligibility, decision considerations for implementation of HAT, devise considerations and devise selection, fitting and verification, and implementation and validation. There are two forms, one for *in-school* and one for *out-of-school*. Depending on your local requirements for IFSP/IEP documentation, portions of this form may be included in the IFSP/IEP.

STEP 1. Potential Candidacy for Remote Microphone HAT

HAT is known to benefit children/youth with hearing, language and/or learning problems by enhancing the teacher's or classmates' voices and minimizing background noise.

This child/youth is a potential candidate for HAT based on documented evidence of hearing, listening or learning problems and has

☐ Normal peripheral hearing. ☐ Abnormal peripheral hearing.

STEP 2. Implementation Considerations for Remote Microphone HAT

Consider the following areas to identify any special challenges that may affect the decision to implement HAT.

1. Acoustical environment

☐ Meets ANSI standards
☐ Transient noise

2. Social-emotional

☐ Motivation (student & teachers)
☐ Attention and fatigue
 – Listening/looking
☐ Self-image
☐ Self-advocacy
☐ Social acceptance
☐ Classroom culture

3. Functional

☐ Age
 – Chronological/developmental
☐ Academic performance
☐ Communication skills

4. Support

☐ Awareness
☐ External acceptance
☐ Ability to use and manage technology

Do these considerations result in any contraindications for fitting HAT?

- If no, then proceed to Step 3, Device Considerations and Selection.
- If yes, then provide counseling, monitor the situation, and review the situation. When appropriate, reconsider the use of HAT.

Step 2 Comments:

§ At this time there is not definitive evidence to support an advantage of bilateral over monaural FM fittings or boom microphone versus lapel microphone versus use of other microphone location (i.e., conference microphone)[61, 99–101]. Further research is needed in this area.

** Ibid.

STEP 3. Device Considerations and Selection

Remote Microphone HAT Goals

These goals represent recommended practice unless individual testing indicates otherwise.

- Audibility and Intelligibility
  - Speech recognition that is commensurate with performance in ideal listening conditions.
  - Full audibility of self and others.
  - Reduced effects of distance, noise and reverberation
- Preferred practice to accomplish full audibility
  - Consistent signal from the talker regardless of head movement[§]
  - Technology that will be worn consistently by the individual, parent and/or teacher.
  - Technology that will provide full audibility according to listener group:
    - Group 1. Children and youth with hearing loss who are actual or potential hearing aid users: Bilateral ear-level wireless technology and fewest equipment adjustments**
    - Group 2. Children and youth with cochlear implants or bone-conduction hearing devices: Bilateral wireless technology.
    - Group 3. Children and youth with normal hearing sensitivity who have special listening requirements: There is not a default HAT arrangement for this population.

STEP 4. Fitting and Verification - see Supplement A. Fitting and Verification Procedures and Worksheet

1. Audiological Considerations

Hearing status:

- ☐ conductive/sensorineural/mixed
- ☐ unilateral/asymmetrical
- ☐ auditory neuropathy spectrum disorder
- ☐ normal

Audiogram:

☐ auditory thresholds ☐ configuration

Speech recognition performance in noise: (please describe)

Stability:

☐ stable ☐ fluctuating ☐ progressive

Special considerations:

☐ drainage ☐ allergy ☐ atresia ☐ other

Current use of hearing technology: (please describe current arrangement and consistency of use)

2. Developmental Considerations

Age:

- ☐ chronological/developmental deficits
- ☐ wearer acceptance

Academic performance:

☐ at or above grade level ☐ below grade level

Additional problems:

☐ attention/hyperactivity	☐ learning
☐ sensory integration	☐ vision
☐ behavior	☐ fine motor
☐ cognition	☐ auditory processing
☐ mobility	

3. Listening Environment Considerations

Measurements:

Ambient Noise Level (unoccupied classroom) _____________

☐ Exceeds 35 dBA (ANSI S12.60-2002)[76]

Teacher's Voice to Noise Ratio (occupied classroom) _____________

☐ Is less than 15 dB

Reverberation Time_____________

☐ Exceeds .6sec (ANSI S12.60-2002)[76]

School learning environment:

☐ lecture	☐ discussion
☐ solo	☐ team teaching
☐ single group	☐ multiple groups
☐ 1:1 in-class service	

School access needs:

☐ teachers	☐ peers
☐ single talker	☐ multiple talkers
☐ structured learning	☐ unstructured learning
☐ technology (computer, TV)	

School acoustic needs:

- ☐ signal sources (intensity & spectrum)
- ☐ noise sources (spectrum & time)
- ☐ reverberation
- ☐ room size and shape
- ☐ student position

Current HATs in use at school:

☐ teacher support ☐ peer support

Other school locations:

☐ auditorium/theater	☐ therapy areas
☐ gymnasium	☐ cafeteria
☐ extra-curricular activities	☐ library
☐ specials: music, computer, resource	

4. Technology Considerations

- ☐ convenience
- ☐ wearability
- ☐ reliability
- ☐ maintenance
- ☐ ease of monitoring
- ☐ manufacturer/dealer support
- ☐ compatibility with existing amplification
- ☐ compatibility with computers, phones, and other devices
- ☐ signal interference
- ☐ multiple FM frequencies

5. Device Determination

Receiver:

- ☐ ear-level FM
- ☐ HA/CI/BD + FM receiver
- ☐ Targeted area ADS
- ☐ Whole classroom ADS
- ☐ other ________________________________

Transmitter/Microphone:

- ☐ proximity mic
- ☐ boom mic
- ☐ lavalier zoom
- ☐ conference mic
- ☐ directional mic

Ear receiver location:

- ☐ monaural __R __L
- ☐ binaural
- ☐ alternating
- ☐ accessories: ____

____

____

Recommended Device:

Step 3 Comments:

STEP 5. Implementation & Validation: Orientation, Training, Usage Plan and Validation

1. Orientation & Training

Child/Youth:

- ☐ implications of hearing loss
- ☐ function of device
- ☐ appropriate use of device and features
- ☐ expectations—benefits and limitations
- ☐ care & maintenance
- ☐ troubleshooting
- ☐ self-monitoring
- ☐ other ________________________________ ____

Teacher/school staff:

- ☐ implications of hearing loss
- ☐ function of device
- ☐ appropriate use of device and features
- ☐ expectations – benefits and limitations
- ☐ maintenance
- ☐ listening check and troubleshooting
- ☐ other ________________________________ ____

2. Usage Plan

- ☐ Full-time
- ☐ Part-time

Specific environments: __________________________
____
____ __

Specific activities:

- ☐ assemblies
- ☐ therapy
- ☐ classroom discussion
- ☐ PE and other organized physical activities
- ☐ Other _________________________________ _

3. Validation

Does the HAT device meet the intended goals? What is the evidence for:

- Audibility and intelligibility of speech that is commensurate with best speech recognition in ideal listening conditions:
  Speech Recognition in ideal listening conditions ______%
  Speech recognition in noise with FM ______%
  Validation Instruments used: ______________________
  ____
- Full audibility confirmed for self:
  ☐ Yes ☐ No
- Full audibility confirmed for others:
  ☐ Yes ☐ No
- Performance:
  Self-assessment ______________________________
  Observation Questionnaire _____________________
  Evaluation ___________________________________

4. Monitoring Plan

Remote Microphone HAT Function:

Procedure used to monitor HAT:

- ☐ Ling 6 sounds
- ☐ Other ______________________________________

Person who will monitor: _____________________________

Location of monitoring: ______________________________

When & how often will HAT be monitored:_______________

Procedure to follow when HAT malfunctions:____________
____

Child/Youth Performance with HAT:

Meeting personal auditory/listening goals?
☐ Yes ☐ No

Achieves communication access with teachers and school staff?
☐ Yes ☐ No

Achieves communication access with peers?
☐ Yes ☐ No

Step 5 Comments:

Remote Microphone HAT Implementation Worksheet

†† At this time there is not definitive evidence to support an advantage of bilateral over monaural FM fittings or boom microphone versus lapel microphone versus use of other microphone location (i.e., conference microphone) 61, 99-101. Further research is needed in this area.

‡‡ Ibid.

B.2. Out-of-School Form

Name ____ **Date** _________

The *HAT Implementation Worksheet* is a five step process to document eligibility, decision considerations for implementation of HAT, devise considerations and devise selection, fitting and verification, and implementation and validation. There are two forms, one for in-school and one for out-of-school. Depending on your local requirements for IFSP/IEP documentation, portions of this form may be included in the IFSP/IEP.

STEP 1. Potential Candidacy for Remote Microphone HAT

HAT is known to benefit children/youth with hearing, language and/or learning problems by enhancing the teacher's or classmates' voices and minimizing background noise.

This child/youth is a potential candidate for HAT based on documented evidence of hearing, listening or learning problems and has

☐ Normal peripheral hearing. ☐ Abnormal peripheral hearing.

STEP 2. Implementation Considerations for Remote Microphone HAT

Consider the following areas to identify any special challenges that may affect the decision to implement HAT.

1. Acoustical Environment
   - ☐ Noise/reverberation levels in typical settings
   - ☐ Distance from speaker(s)
2. Social-emotional
   - ☐ Motivation (child & family members)
   - ☐ Attention and fatigue
     - listening/looking
   - ☐ Self-image
   - ☐ Self-advocacy
   - ☐ Social acceptance
   - ☐ Family support
3. Functional
   - ☐ Age
     - chronological/developmental
   - ☐ Communication Skills
   - ☐ Communication Environment
4. Support
   - ☐ Awareness
   - ☐ External acceptance
   - ☐ Ability to use and manage technology
   - ☐ Financial resources
   - ☐ ADA obligations

STEP 4. Fitting and Verification - see Supplement A. Fitting and Verification Procedures and Worksheet

Do these considerations result in any contradictions for fitting HAT?

- If no, then proceed to Step 3, Device Considerations and Selection.
- If yes, then provide counseling, monitor the situation, and review the situation. When appropriate, reconsider the use of HAT.

Step 2 Comments:

STEP 3. Device Considerations and Selection

Remote Microphone HAT Goals

These goals represent recommended practice unless individual testing indicates otherwise.

- Audibility and Intelligibility
  - Speech recognition that is commensurate with performance in ideal listening conditions.
  - Full audibility of self and others.
  - Reduced effects of distance, noise and reverberation.
- Preferred practice to accomplish full audibility
  - Consistent signal from the talker regardless of head movement.[††]
  - Technology that will be worn consistently by the individual, parent and/or teacher.
  - Technology that will provide full audibility according to listener group:
    - Group 1. Children and youth with hearing loss who are actual or potential hearing aid users: Bilateral ear-level wireless technology and fewest equipment adjustments.[‡‡]
    - Group 2. Children and youth with cochlear implants or bone-conduction hearing devices: Bilateral wireless technology.
    - Group 3. Children and youth with normal hearing sensitivity who have special listening requirements: There is not a default HAT arrangement for this population.

1. Audiological Considerations

Hearing Status:

- ☐ conductive/sensorineural/mixed
- ☐ unilateral/asymmetrical
- ☐ auditory neuropathy spectrum disorder
- ☐ normal

Audiogram:

- ☐ auditory thresholds
- ☐ configuration

Speech recognition performance in noise: (please describe)

Stability:

☐ stable ☐ fluctuating ☐ progressive

Special considerations:

☐ drainage ☐ allergy ☐ atresia ☐ other

Current use of hearing technology: (please describe current arrangement and consistency of use)

2. Developmental Considerations

Age:

- ☐ chronological/developmental deficits

Academic performance/school readiness:

- ☐ at or above grade/developmental level
- ☐ below grade/developmental level

Additional problems:

- ☐ attention/hyperactivity
- ☐ sensory integration
- ☐ behavior ☐ learning
- ☐ cognition ☐ vision
- ☐ mobility ☐ fine motor
- ☐ auditory processing

3. Listening Environment Considerations

Measurements:

Ambient Noise Level (unoccupied room) ______________

- ☐ exceeds 35 dBA (ANSI S12.60-2002)[76]

Speaker's Voice to Noise Ratio (occupied room) ______________

- ☐ is less than 15 dB

Reverberation Time______________

- ☐ exceeds .6sec (ANSI S12.60-2002)[76]

Home Activity Needs:

- ☐ meals
- ☐ play – structured activities (e.g., reading)
- ☐ play – single/multiple groups structured

Home Access Needs:

- ☐ family, friends, peers
- ☐ single/multiple talkers
- ☐ structured activities
- ☐ unstructured activities
- ☐ audio visual technology (TV, DVD, stereo, computer)

Home Acoustic Needs:

- ☐ signal sources (intensity & spectrum)
- ☐ noise sources (spectrum & time)
- ☐ reverberation
- ☐ room size and shape
- ☐ child position
- ☐ wireless interference

Other locations:

- ☐ recreation
- ☐ Church
- ☐ community
- ☐ therapy

4. Technology Considerations

- ☐ convenience
- ☐ wearability
- ☐ reliability
- ☐ maintenance
- ☐ ease of monitoring
- ☐ manufacturer/dealer support
- ☐ compatibility with existing amplification
- ☐ compatibility with computers, phones, and other devices
- ☐ signal interference
- ☐ multiple FM frequencies

5. Device Determination

Receiver:

- ☐ ear-level FM
- ☐ HA/CI/BD + FM receiver
- ☐ Targeted area ADS
- ☐ Whole classroom ADS
- ☐ other ________________________________

Transmitter/Microphone:

- ☐ proximity mic
- ☐ boom mic
- ☐ lavalier zoom
- ☐ conference mic
- ☐ directional mic

Ear receiver location:

- ☐ monaural __R __L
- ☐ binaural
- ☐ alternating
- ☐ accessories: ________________________________

____

____

Recommended Device:

Step 3 Comments:

STEP 5. Implementation & Validation: Orientation, Training, Usage Plan and Validation

1. Orientation & Training

Child/Youth:

- ☐ implications of hearing loss
- ☐ function of device
- ☐ appropriate use of device and features
- ☐ expectations—benefits and limitations
- ☐ care & maintenance
- ☐ troubleshooting
- ☐ self-monitoring
- ☐ other ____

Parent/caregiver:

- ☐ implications of hearing loss
- ☐ function of device
- ☐ appropriate use of device and features
- ☐ expectations – benefits and limitations
- ☐ maintenance
- ☐ listening check and troubleshooting
- ☐ other ______________________________

2. Usage Plan

☐ Full-time ☐ Part-time

Specific environments:

- ☐ Car
- ☐ Other ____

Specific activities:

- ☐ group interaction
- ☐ large group presentation
- ☐ one:one interation
- ☐ organized physical activities
- ☐ informal activities
- ☐ other ____

3. Validation

Does the HAT device meet the intended goals? What is the evidence for:

- Audibility and intelligibility of speech that is commensurate with best speech recognition in ideal listening conditions:
  Speech Recognition in ideal listening conditions _____%
  Speech recognition in noise with FM _____%
  Validation Instruments used: ______________________________
- Full audibility confirmed for self:
  ☐ Yes ☐ No
- Full audibility confirmed for others:
  ☐ Yes ☐ No
- Performance:
  Self-assessment ________________________
  Observation Questionnaire __________________
  Evaluation ______________________________

4. Monitoring Plan

Remote Microphone HAT Function:

Procedure used to monitor HAT:

- ☐ Ling 6 sounds
- ☐ Other ______________________________

Person who will monitor: ______________________

Location of monitoring: ______________________________

When & how often will HAT be monitored:__________

Procedure to follow when HAT malfunctions:__________

Child/Youth Performance with HAT:

Meeting personal auditory/listening goals?

☐ Yes ☐ No

Achieves communication access with teachers and school staff?

☐ Yes ☐ No

Achieves communication access with peers?

☐ Yes ☐ No

Step 5 Comments:

Glossary of Terms

Acoustic Gain
The amount by which an amplification system increases the decibel level of sound.

Amplitude Modulation (AM)
A method by which a radio signal is used to carry a sound signal. Essentially, the amplitude of the radio signal is changed (modulated) in step with the pressure variations of the sound signal. (see also, Frequency Modulation).

Amplitude
The “size” or “magnitude” of a sound. Amplitude is usually expressed in decibels.

Antenna
A conductor, often a wire, which radiates or detects radio waves. (see FM Transmitter and FM receiver).

Automatic Gain Control
Gain falls as the decibel level of the input signal rises. As a result, the decibel level of the output rises at a slower rate than that of the input. (see Input and Output).

Behavioral Evaluation
Measuring amplification benefit in terms of speech recognition by the intended user. (see also, Electroacoustic Evaluation).

Bluetooth
A protocol developed to standardize communication among wireless devices. At the time of writing, the processing and current demands prevent the incorporation of Bluetooth technology into hearing aids. Methods and devices exist, however, by which signals from Bluetooth devices (such as cell phones and MP3 players) can be relayed to a hearing either by direct connection or by a secondary wireless link.

Bone-Conduction Hearing Device
A hearing aid that transmits the signal via bone-conduction. These may be (a) headband-anchored devices in which an oscillator is placed on the skull (typically behind the ear) or (b) bone-anchored devices in which an oscillator is attached to a fixture that has been osseointegrated into the skull.

Classroom Audio Distribution System (ADS)
As defined by ASA/ANSI s12.60.2010, American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1 Permanent Classrooms, is a system whose primary design goal is to electroacoustically distribute the audio portion of spoken communications and curricular content throughout the learning space or targeted listening area. This content may include, but is not limited to, live voice sources from teachers and peers, as well as prerecorded and/or streaming media content from various sources, or both. The systems are not typically designed for public address purposes (such as building-wide announcements) or for the delivery of alert or warning signals, though they may include these capabilities. Classroom audio distribution systems may also include provisions to assist persons with low-amplitude voice levels or those with certain hearing conditions (pp 4-5).

Compression Amplification
An amplification system in which gain falls as the decibel level of the input signal rises. (see also, Automatic Gain Control).

Compression Limiting
A method of output limiting in which constant output is maintained by matching increases of input level with an equal decrease of gain. (see Output Limiting and Peak Clipping).

Daisy Chain
In this context, a technique in which a wireless microphone transmits to a second microphone, which transmits the combined sound to a third microphone, and so on. The last microphone in the chain transmits to the listener. In practice, the chain is usually limited to two microphones – one for the teacher and one either to pass around or to be used by an aide.

dB HL (dB Hearing Level)
The decibel level of a sound in relation to the threshold of detection of that sound by an average person with normal hearing.

dB SL (dB Sensation Level)
The decibel level of a sound in relation to the threshold of detection of that sound by the individual who is listening.

dB SPL (dB Sound Pressure Level)
The decibel level of a sound in relation to a standard level defined for purpose of sound measurement.

Electroacoustic Evaluation
Measuring the performance of an amplification system in terms of sound amplitude and signal-to-noise ratio. (See Behavioral Evaluation, Amplitude, and Signal-to-Noise ratio).

FM Channel
A narrow range of radio frequencies within the band allocated for FM amplification. Each channel is identified by number, letter, or color. The transmitter and the receiver must be set to the same channel.

FM Level Advantage
Defined, here, as the increase in decibel output level when the FM signal is added to, or substituted for, the signal from the aid's own microphone.

FM Receiver
The device that detects the transmitted radio wave and recovers the sound signal for delivery to the hearing aid or other hearing device. Connection options include:

- Integrated—receiver is built-into the personal device
- Dedicated—the receiver is compatible with one case design
- Universal—receiver works with multiple devices depending on the interface between the device and the receiver, i.e., a 3 pin polarized connection).

FM SNR Benefit
Defined here as the increase in signal-to-noise ratio when the FM signal is added to, or substituted for, the signal from the aid's or CI's own microphone. (see Signal-to-Noise Ratio).

FM Transmitter

[§§] Adapted from L. Klopp (2005) by Cheryl DeConde Johnson. From Johnson, C.D. & Seaton, J. In Press. Educational Audiology Handbook, 2nd Edition. Thomson Learning Inc.

The device that transmits the radio signal that carries the sound signal. Sometimes the microphone and transmitter are incorporated into a single unit.

FM Transparency
The condition in which equal inputs to the FM and hearing aid microphones produce equal outputs from the hearing aid. (Operationally defined, here, for an input of 65 dBSPL).

Frequency Modulation (FM)
A method by which a radio signal is used to carry a sound signal. Essentially, the frequency of the radio signal is changed (modulated) in step with the pressure variations of the sound signal. (See also, Amplitude Modulation).

Frequency Response
The relationship between gain or output and frequency.

Gain (See Acoustic Gain)

Induction Loop
A loop of wire that is connected to the output of an amplifier. The current flowing through the wire is instep with the speech signal and generates a fluctuating magnetic field. A telecoil in the hearing device detects the fluctuations and passes them directly to the hearing device's amplifier. Note that a loop system differs from FM, AM and Infrared systems in that no wireless carrier is used.

Infrared (IR)
A region of the electromagnetic spectrum that is just below the visible region. Infrared waves are essentially very high frequency radio waves and can be used as a carrier wave in a remote-microphone system. Infrared is commonly used as a carrier in remote controls for TVs and VCRs.

Input
The signal entering the microphone of a hearing aid, a cochlear implant or an FM system. Input level is typically specified in dB SPL.

Linear Amplification
An amplification system in which gain does not change with the decibel level of the input (until the output reaches its maximum level and Output Limiting occurs). (see, also, Compression Limiting).

Microphone
A device that converts a sound signal into an analogous electrical signal.

- Beam-forming microphone—A highly directional microphone.
- Boom microphone—Held close to the mouth by a support over the ear or on a head band.
- Cheek microphone—A miniature boom microphone held at the cheek by a support over the ear.
- Conference microphone—An omni-directional remote microphone designed to be placed in the center of a group of talkers.
- Local microphone—Worn by the listener; typically it is the hearing aid microphone.
- Directional microphone—More sensitive in some directions than in others.

- Environmental microphone—A term used in the past to refer to the local microphone.
- Lapel microphone (aka tie-clip)—Can be clipped to the tie or other item of clothing.
- Lavalier microphone—Attached to a cord worn around the neck.
- Omni-directional microphone—Equally sensitive in all directions.
- Remote microphone—At some distance from the listener, typically worn by the talker.

Output Limiting
A process for preventing the decibel level of the output of an amplification system from exceeding a predetermined level. (see peak clipping and compression limiting).

Output
The signal leaving the amplification system. Output level is typically specified in dB SPL. It may be measured in the ear canal of a listener or in a test coupler intended to mimic an average ear. (see Real-Ear Measurement).

Peak Clipping
A method of output limiting in which constant output is maintained by removing the peaks of the sound waveform. (see Output Limiting and Compression limiting).

Real-Ear Measurement
Measuring the output of a hearing aid in the listener's ear (see Output).

Receiver
In this context, receiver applies to the device that detects the wireless signal, extracts the speech signal, and passes it on to the hearing aid or other hearing device. The receiver may be a separate unit or may be built into the hearing device.

- AM receiver extracts speech from amplitude-modulated signals;
- Bluetooth receiver negotiates with a Bluetooth transmitter and extract speech from the transmitted signal;
- FM receiver extracts speech from frequency-modulated signals;
- Infrared (IR) receiver extracts speech from IR signals

Shoe (boot)
In this context, an adapter that is placed on a hearing aid to permit the connection of FM receivers or other accessories.

Signal-to-Noise Ratio (SNR)
The amount in decibels by which the amplitude of the desired signal (usually speech) exceeds that of an interfering signal.

Streaming
The continuous transfer of data for immediate processing or playback (Merriam-Webster Collegiate Dictionary). Audio streaming is the digital transmission of an audio signal to a hearing instrument.

Telecoil (T-coil)
A feature of some (but not all) hearing aids that detects fluctuating magnetic fields, converts them to fluctuating voltage, and passes them to the amplifier of a hearing device. Originally developed to facilitate telephone use, the telecoil can also be used as the receiver in a remote-microphone loop system.

Transparency
The condition in which equal inputs to the wireless and local microphones generate equal outputs from the hearing device.

APPENDIX D

Common Functional Outcome Measures Used to Assess Amplification Benefit§§

Note: Instruments that are shaded are specifically designed as amplification validation tools.

INSTRUMENT	TARGET POPULATION	DESCRIPTION	GOAL/PURPOSE
Children's Home Inventory for Listening Difficulties (CHILD)[145]	Ages 3-12	Parent/caregivers judge 15 situational listening behaviors using an 8-point scale on the "Understand-O-Meter". An average score can be computed to compare ratings of different individuals, listening skill improvement over time, or amplification benefit. Children who are 7-8 years can be administered the inventory either through interview or by reading the questions themselves.	To assess perceptions of listening behavior and subsequent communication needs; may be used to determine current ability, monitor progress over time, or evaluate the benefits of amplification devices or other accommodations.

Supplement A. Fitting and Verification Procedures for Ear-Level FM

Contents

Fitting Goals

These goals represent recommended practice unless individual testing indicates otherwise.

- Audibility and Intelligibility
    - Speech recognition that is commensurate with performance in ideal listening conditions.
    - Full audibility of self and others.
    - Reduced effects of distance, noise and reverberation.
- Preferred practice to accomplish full audibility
    - Consistent signal from the talker regardless of head movement[1].
    - Technology that will be worn consistently by the individual, parent and/or teacher.
    - Technology that provides full audibility varies across listener groups. Each of these groups will be addressed individually in this Supplement (SA).
        - SA 1: Group1. Children and youth with hearing loss who are actual or potential hearing aid users: Bilateral ear-level wireless technology with fewest equipment adjustments[2].
        - SA 2: Group 2. Children and youth with cochlear implants: Bilateral wireless technology.
        - SA 3: Group 3. Children and youth with normal hearing sensitivity who have special listening requirements: There is not a default HAT arrangement for this population.

Verification Terminology

Some basic terminology standards are needed when describing the remote microphone HAT evaluation. The following is proposed to introduce some standardization to the process (see appendix for further illustrations of terms). Abbreviations that describe the type of evaluation, the device(s) being evaluated and the input level used, create a simple shorthand that quickly describes the measurements completed (see SA 4., Summary of Evaluation Steps for Verification of Ear-Level FM Systems).

- The type of evaluation would be described as E = electroacoustic; R = real ear; or B = behavioral.
- The devices would be listed as HA = hearing aid only; FM = FM only; FM/HA = FM evaluated in the FM+HA setting; HA/FM = hearing aid evaluated in the FM+HA setting; CI = Cochlear Implant.
- Input levels would be specified in dB_{SPL} or $_{HL}$. If testing is completed in noise, the presentation level of the signal is listed first, followed by the level of the noise. For example, when testing behaviorally in the sound field, $50/50_{HL}$ indicates the primary signal is presented at 50 dB HL and noise is presented simultaneously at 50 dB HL for a 0 dB signal-to-noise ratio.
- An abbreviation of $EHA/FM65_{SPL}$ would indicate that electroacoustic evaluation of the HA response was evaluated in the HA+FM setting with a 65 dB SPL input level.

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1. At this time there is not definitive evidence to support an advantage of bilateral over monaural FM fittings or boom microphone versus lapel microphone versus use of other microphone location (e.g., conference microphone) (Pittman, Lewis, Hoover, & Stelmachowicz, 1999; Kreisman & Crandell, 2002; Lewis, Crandell, Valente, & Enrietto Horn, 2004; Tharpe, Ricketts, & Sladen, 2004). Further research is needed in this area.

2. Ibid.

SA1. Group 1: Children and Youth with Hearing Loss Who Are Actual or Potential Hearing Aid Users

FM systems are commonly coupled directly to personal hearing aids. With such couplings, the potential exists for interactions between these two technologies. To achieve goals for audibility and intelligibility, it is important that audiologists verify performance of FM fittings on an individual basis. This section provides step-by-step electroacoustic and behavioral verification procedures for ear-level FM systems coupled to personal hearing aids.

SA1.1. Ear-Level FM Transmitter Features

Ear-level FM systems consist of an FM transmitter worn by the talker and an FM receiver worn on the ear by the listener. The basic features of these systems are reviewed in the following table with possible options provided for each feature (Thibodeau, 2004).

Feature	Variations	Options	Pros	Cons
Microphone	Location	External (Lapel)	Clips easily onto clothes	More likely to pick up noise from clothes Located farther away from talker's mouth If talker turns head, intensity of microphone signal may vary
		External (Head boom, cheek boom)	Keeps microphone close to the talker's mouth at all times	Uncomfortable and distracting for some talkers
		Internal (Lavalier)	Easy to hang around neck of talker No microphone cord to snag or break	More likely to pick up noise from clothes Located farther away from talker's mouth If talker turns head, intensity of microphone signal may vary
		Conference	Used in groups or at a table Picks up the voices of multiple talkers	Diminished SNR due to distance from talker
	Type	Omni-directional	Sensitivity in all directions	May transmit more noise, especially in large crowds
		Directional Fixed	Able to focus on selected signal with less amplification of surrounding noise	If positioned incorrectly, the talker's voice may be attenuated
		Directional User Select	User can change the directionality when needed to improve signal reception	Additional buttons for selection may be confusing

Feature	Variations	Options	Pros	Cons
Channel	Number	Single Fixed	Easy for personal use – don't have to worry about changing channels	May cause interference with other FM users in a confined space (e.g., school)
		Multi-channel Selectable	If interference is encountered, can change channel easily; Adds flexibility for use of multiple FM systems in schools	Options for multiple channels adds complexity and may result in getting on the wrong channel inadvertently
	Frequency	72-76 mHz	Compatible with older FM equipment	Prone to interference from unwanted sources
		216-217 mHz	Less interference; smaller receivers	Not compatible with older FM equipment
	Synthesis	Direct (user changes channel)	User is in control of switching channels	May be tedious if having to change channels for multiple users
		Automatic (channel changes when in close proximity to receiver)	Convenient when changing channels for more than one user	Can cause confusion when large group of FM users is in close proximity –channels may change inadvertently
Controls	AGC	Trimpot	Easy to adjust without connecting to PC	Can inadvertently be changed
	Volume	Dial	Easy to adjust without connecting to PC	Can inadvertently be changed
Programmable	Channels	Reduce number to those frequently used	Do not have to cycle through channels that are never used	May restrict flexibility to move equipment to other classrooms

Feature	Variations	Options	Pros	Cons
Batteries	Type	NiCad Only	Rechargeable battery is cost efficient over long term use	Expensive in the short term; Need backup in case of battery failure; need access to electrical outlet
		NiCad and Alkaline	Increased flexibility in case of emergency	Chance of mistakenly charging alkaline battery and damaging system
	Replace-ment	User Access	Convenient for user	Increased chance of user error
		Manufacturer Only	Decreases chance of damage to device	Inconvenient for user if battery needs to be replaced
Indicator Lights	On Front	Low Battery	Alerts user to change/ charge battery	May be distracting in public venue with limited lighting such as a play
		FM Transmission	Alerts user to function of device	May be distracting in public venue with limited lighting such as a play
Accessory Jacks		Audio Input Jack	Increases flexibility of device (for use with other devices)	May be confused with jack for charging
Secondary Transmission	Bluetooth		Allows user to use cellular phone with FM device	Decreases battery life of transmitter

SA1.2. Ear-Level FM Receiver Features

Feature	Variations	Options	Pros	Cons
Location	Self-Contained	FM Receiver within BTE case	Convenient use – no additional parts needed	If receiver needs repair, entire HA has to be sent in
	Interface with Hearing aid	Receiver attaches to BTE via audio shoe	Can be used with many different hearing brands of HA	Audio shoe adds another part with the potential to malfunction
Channel	Number	Single Fixed	Easy for personal use – don't have to worry about changing channels	Less flexibility
		Multi-channel Selectable	Good for use in close proximity to other FM users (e.g. schools) Can be automatically changed to specific channel by transmitter	May be confusing for some users
	Frequency	72-76 mHz	Compatible with older FM equipment	Receive interference from cellular devices
		216-217 mHz	Less interference due to cellular devices	Will not be compatible with older FM equipment
Batteries	Type	Zinc Air	Small – allows devices to be smaller	No rechargeable option
Programmable	Frequencies	Default Channel	Simplifies the startup for the user so that when turned on, correct channel is received	If transmitting situation changes, default may no longer be appropriate
		Channel Set	Reduces chance of inadvertently getting to wrong channel	Not as flexible if situation changes or equipment needed as backup
	FM/HA ratio	Adjust level of FM signal re: mic signal	Allows for customization of system for specific situations and user needs	May require PC to adjust settings
	Gain/Output	Adjust gain and output of BTE	Some devices can be adjusted without connecting to PC	Possibility of inadvertently changing HA settings

Feature	Variations	Options	Pros	Cons
Switches	Indicator Lights	Continuous or interrupted	May indicate reception of FM signal May indicate low battery function	May not give indication if battery exhausted May decrease battery life
	Program-mable	FM, FM+HA, HA	Can set start-up option	Requires computer/ software to change options Cannot confirm setting visually Inadvertent change
	Mechanical	FM, FM+HA, HA	Can check settings visually	Requires manual dexterity Inadvertent change

SA1.3. Ear-Level FM Verification Procedures

Verification procedures are necessary to demonstrate whether the device is functioning according to pre-determined targets.

In most cases, ear-level FM systems use the microphone of the hearing aid as the local microphone of the system. The frequency and gain/output characteristics of the FM portion of the system are determined by the hearing aid settings and/or programming. All verification measures of the relationship between the FM and HA microphones are based on the assumption that the hearing aid portion of the system has been adjusted to provide appropriate audibility and output for the individual child. (American Academy of Audiology, 2004; Bagatto, Moodie, Scollie, et al., 2005; Scollie, Seewald, Cornelisse, et al., 2005; Seewald, Moodie, Scollie, & Bagatto, 2005; Byrne & Dillon, 1986; Byrne, Dillon, Ching, Kasch, & Keidser, 2001). It is incumbent upon the audiologist to ensure that this assumption is correct prior to the FM evaluation. Any adjustments to personal hearing aid settings should always be made in collaboration with the dispensing audiologist.

SA1.3.1. Verification Priorities

Previous FM guidelines (American Speech Language Hearing Association, 2002) have recommended a number of essential verification points that continue to be important priorities in the verification process.

- Under normal conditions of use, the FM system should increase the level of the perceived speech, in the listener's ear, by at least 10 dB relative to reception by hearing aid only.
- If simultaneous use of the FM and HA microphone is the rule for a given individual, the assessment of the FM and HA should be performed in the FM+HA position.
- It is advisable to assess performance electroacoustically with a speech-weighted input, using the same type of signal for both HA microphone and FM system. With today's advanced test systems, the use of a calibrated real speech signal is preferred over speech-weighted noise inputs.
- True estimates of the maximum output of the system are obtained from the HA microphone, not the FM micro-phone, due to the presence of input AGC in the FM system.

- Speech perception measures with FM can be completed as a behavioral verification option, with priority given to testing in noise under the FM+HA condition.

SA1.4. Electroacoustic Verification

The main purpose of remote microphone HAT, as discussed here, is to increase the speech-to-noise ratio. This goal is automatically attained within the wireless signal - at least for the talker with a properly positioned wireless microphone. But the local microphone on the hearing aid (or cochlear implant) will normally remain active and it is possible for this microphone to reintroduce the noise and reverberation that the personal wireless system was intended to eliminate. The challenge then becomes one of adjusting the wireless system so as to preserve as much of the speech-to-noise benefit as possible[3]. It can be shown that this requirement is best met under the criterion of Transparency, defined here as the condition in which equal inputs to the wireless and local microphones generate equal outputs from the hearing device. There are, however, some practical difficulties in translating this criterion into a measurement procedure. If, for example, the input is high enough to drive the hearing aid into saturation or compression limiting, the condition of equal output for equal input can apparently be met over a wide range of inappropriate adjustments. Moreover, any expansion, wide-dynamic-range compression, or compression limiting in the wireless transmitter will make it impossible to maintain the equal output criterion over a range of input levels. Therefore, the following operational definition of Transparency is proposed:

> Operational definition: **Transparency in an ear-level FM system is attained when inputs of 65 dB SPL to the wireless and hearing aid microphones produce equal outputs from the hearing aid.**

This definition is immediately translatable into a procedure for initial adjustment of the personal wireless system and for verifying adjustments[4]. There are, however, several considerations which include:

- Any difference in frequency response between the hearing-aid microphone and the wireless microphone will cause departures from transparency as frequency is changed. It is, therefore, recommended that the comparison be made with a speech input.
- Compression in the wireless transmitter will cause departures from transparency as input level is changed. Behavioral validation should be used to determine whether, and in what direction, deviations from the criterion of transparency, as defined above, are needed by individual students.
- The adjustment and verification procedure recommended here is not invalidated by compression in the hearing aid because this acts equally on the two signals (Platz, 2004, 2006). The only exception is, as mentioned above, when the inputs drive the hearing aid into saturation or compression limiting. In this case the effect of adjustment to the wireless signal will not be observable.

A step-by-step guide to electroacoustic verification can be found in section SA1.6.1. of this Supplement.

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3. It is assumed that the hearing aid or cochlear implant has already been fitted or programmed to provide optimal speech audibility without discomfort, over a range of inputs from soft conversational speech to loud speech (including the self-generated speech of the student).

4. The criterion used in the ASHA (2002) guidelines is that an input of 80 dB SPL to the wireless microphone should give a 10 dB higher output than an input of 65 dB SPL to the hearing aid microphone. This has been referred to as an FM Level Advantage. As both hearing aids and personal wireless systems have acquired more complex non-linear input/output characteristics it has become increasingly difficult to ensure that attainment of this criterion satisfies the need for optimization of signal-to-noise ratio under the FM+HA condition. It is for this reason that the criterion of transparency is recommended.

SA1.4.1. Not recommended

Unlike the ASHA 2002 Guidelines, it is not recommended that FM verification procedures be completed using high level inputs to the FM microphone when comparing FM to HA responses. Uncertain parameters for compression in hearing aids will render such measures of the FM response invalid. Instead, current test systems and hearing aid processing features require that input levels to the FM microphone are less than actual use inputs in order to assure that the FM response has the same compression characteristics as the HA response.

SA1.5. Behavioral Verification

The purpose of behavioral verification is to confirm that the selected remote microphone HAT functions as expected on a student/child. Primarily, behavioral verification is completed in a noise environment to compare student performance with a hearing aid alone to performance with an FM microphone also active. Although improved performance in noise with the FM active is the expected outcome, behavioral verification is not expected to replicate the student's performance in their specific listening environment(s). Another goal is to confirm that performance in ideal listening conditions with the FM system is commensurate with the student's best performance with their appropriately fit hearing aid(s) alone. Behavioral verification can also be used to compare performance across test sessions to monitor the stability of the student's responses over time and to verify that the HAT system continues to function as expected.

SA1.5.1. Test Stimuli

Behavioral verification of FM performance can be completed using a variety of speech recognition measures to confirm that the selected HAT functions as expected. While they are most often completed in clinical settings, behavioral verification measures using speech stimuli should be completed under conditions that are as representative as possible of typical listening environments for the child/youth. Priority should be given to testing in the presence of background noise and should compare performance in the aided-only condition ("BHA" in noise) to performance with the FM microphone also active ("BFM/HA") with the same noise conditions present.

- When speech measures are being used for verification purposes, the vocabulary level and language competence of the child must be considered. Typically, behavioral speech testing uses word or sentence repetition tasks. Low-redundancy materials (e.g. isolated words) are preferable over sentence materials, as sentences will allow the listener to compensate for the presence of noise masking. Appropriate modifications may be required based on the child's receptive or expressive performance, as well as his or her primary language. Examples of tests in English include: WIPI (Word Intelligibility by Picture Identification, Ross & Lerman, 1970), NU-CHIPS (Northwestern University Children's Perception of Speech, Katz & Elliott, 1978), NU-6 (Tillman & Carhart, 1966), CASPA (Computer-Assisted Speech Perception Assessment, Mackersie, Boothroyd, & Minnear, 2001), and VidSpac (Video-game test of the perception of Speech Pattern Contrasts, Boothroyd, Hanin, Yeung, & Chen, 1992).

- When comparing performance across listening conditions (e.g., in noise with no FM vs. in noise with FM) it is important to understand whether differences in scores represent significant differences in performance. A number of tools are available that provide information to assist the clinician in determining significant differences (Boothoyd, 2008; Thibodeau, 2002; Thornton & Raffin, 1978)

- Appropriate competing noise stimuli would be speech-weighted noise or multi-talker speech babble. Evidence indicates that speech babble is a more efficient masker when compared to spectrally matched composite-noise stimuli, as long as the multi-talker babble consists of at least 4 different talkers (Lewis, Benignus, Muller, Malott, & Barton, 1988). Further details about specific speech and noise levels are found in the worksheet for behavioral verification measures in SA1.6.2 of this Supplement.

- When selecting speech recognition tests, it is important to recognize that list equivalency in quiet does not ensure list equivalency in noise (e.g., Chermak, Pederson, & Bendel, 1984; Chermak, Wagner, & Bendel, 1988). Speech recognition tests are available for which normative data have suggested list equivalency in noise (e.g., HINT [Nilsson, Soli, & Sullivan, 1994], HINT-C [Nilsson, Soli, & Gelnett, 1996], BKB-SIN [Etymotic Research, 2005] , Quick-SIN [Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004]).

- Recommended Speech Levels: 50 dB HL (65 dB SPL) to represent the teacher's voice at a listening distance of 2 meters (Pearsons, Bennett, & Fidel, 1977). A variety of presentation levels could be considered to represent different listening distances, such as 55 dB HL (70 dB SPL) to represent the teacher's voice at a listening distance of 1 meter, or 40 dB HL (55 dB SPL) to represent conversational levels of speech from 2 meters.

- Recommended Noise Levels: 50 dB HL (65 dB SPL) to represent average diffuse background noise levels in a classroom and a 0 signal-to-noise ratio. A +5 dB signal-to-noise ratio may be considered if the child's classroom environment warrants evaluation at a better signal-to-noise ratio.

SA1.5.2. Test Environment

The configuration of the test environment for speech verification will depend, in large part, on known variables of the sound field. There are two primary test configurations:

SA1.5.2.1. Behavioral Test Configuration #1 (see Figure SA1)

Testing using monitored live voice (MLV) presentation with the examiner wearing the FM microphone on the tester side of the sound booth and noise presented via loudspeaker(s) (ASHA, 2002). This is the only behavioral verification option available in single loudspeaker test environments.

SA1.5.2.2. Behavioral Test Configuration #2 (see Figure SA2)

Testing using recorded speech tests with the FM microphone placed 3-6 inches from one loudspeaker and noise presented from 1 or more different loudspeakers is shown in Figure SA2 (Boothroyd, 2004; Lewis, Crandell, Valente, Enrietto Horn, 2004; Schafer & Thibodeau, 2006).

- Due to the close proximity of the FM microphone to the loudspeaker in this configuration, the near-field effects of the loudspeaker must be known in advance. Loudspeakers with bass and treble components spaced farther apart may not have a flat or stable frequency response in the near field and testing with the FM microphone placed 3-6 inches away is not recommended (Lewis, 1992). Single-cone loudspeakers are required in this configuration.

- The SPL at both the calibrated position and the 3 or 6 inch position from the loudspeaker must be known. This confirms that the input level to the FM microphone is consistent with typical inputs to the FM microphone in actual use, while presenting an appropriate input level to the hearing aid microphone at the calibrated position.

- If speech and noise signals are presented from the same loudspeaker(s), placing an FM microphone 3-6 inches from the loudspeaker will not improve performance as it will increase both the level of the talker's voice and the level of the noise equally to the FM microphone. This would maintain the same signal-to-noise ratio that is presented to the hearing aid microphone and would not indicate the real signal-to-noise improvement available from a remote FM microphone.

Loudspeaker arrangements may vary from booth to booth. A single loudspeaker arrangement would rule out the second configuration. Multiple loudspeaker arrangements may be possible. Performance may differ with noise presented at different azimuths (e.g. 180 versus 45 degrees), especially with the system evaluated in the FM+HA mode of operation. The specific location of loudspeakers may be determined by the location of noise sources in a child's classroom environment. The tester/audiologist needs to be aware of the azimuth used for SF calibration for the test booth used.

SA1.5.3. Not recommended

SA1.5.3.1. Functional Gain and/or Amplified Sound Field Threshold (ASFT)

ASFT procedures with pure-tone or warble-tone stimuli are never recommended for behavioral verification of FM performance. These threshold measures use low input levels to the FM microphone and do not indicate how the system responds to the higher input levels of speech that are typical of FM systems in actual use. When nonlinear FM systems are combined with nonlinear hearing aid amplification, amplified sound field thresholds produce responses that have little or no predictable relationship to real use performance.

SA1.5.3.2. Adaptive speech-in-noise testing

Adaptive tests (such as the HINT [Nilsson, Soli, & Sullivan, 1994], HINT-C [Nilsson, Soli, & Gelnett, 1996],) and tests that vary the speech and/or noise level (e.g., BKB-SIN [Etymotic Research, 2005] , Quick-SIN [Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004]) have been used with FM studies in a variety of ways (Boothroyd, 2004; Lewis, et al., 2004; Schafer & Thibodeau, 2006; van der Beek, Soede, & Frijns, 2007). However, such approaches have not been standardized for use in the clinical verification of performance with FM systems. Moreover, when testing is conducted with varying speech and a fixed noise level, the input to the FM microphone will most likely be well below that found in normal use. Similarly, when testing is conducted with varying noise and a fixed speech level at the FM microphone, the resulting noise levels may exceed typical classroom noise levels. For these reasons, the use of such testing to determine a threshold signal-to-noise ratio is not recommended for behavioral FM verification.

SA1.5.3.3. Testing in FM-only mode

While there may be some occasions when operation in the FM-only mode is appropriate, FM systems are most often used in the FM+HA mode. This mode permits the user to hear his or her own speech and the speech of talkers who are nearby. Verification of the true benefit of the FM system, therefore, requires comparison of HA-only with FM+HA conditions (American Speech Language Hearing Association, 2002; Boothroyd, 2004; Lewis, et al., 2004). A comparison of HA-only with FM-only could give misleading results and would fail to show any loss of benefit caused by departure from the criterion of transparency.

SA1.6. Electroacoustic Verification Steps

1. Verification can be completed with any hearing aid test system that has speech-like or calibrated speech signals. When a calibrated speech input signal is not available, turn OFF automatic feedback control and/or noise reduction (if possible).

2. HA is verified for optimal audibility and maximum output for the individual user, using real-ear measures or 2cc coupler plus individually measured RECDs (Real-Ear-to-Coupler Differences).

   NOTE: The only real-ear measurement that is recommended for integrated ear-level HA / FM systems is the verification of the HA settings to ensure full audibility of self and other students. All further measurements comparing FM and HA responses will be completed using the 2cc coupler.

3. Evaluate $EHA65_{SPL}$ **without** the FM receiver attached.

4. Attach FM receiver to HA and set FM Receiver to manufacturer's DEFAULT setting. FM transmitter should be turned ON and set to MUTE.

5. Evaluate EHA/FM65_{SPL} and compare to results of EHA65 to determine if there are impedance or program changes to the HA response with an FM receiver attached. Record on worksheet. (For further discussion of possible impedance or programming effects, see Platz, 2004.)

6. With HA still attached to the 2cc coupler and test microphone, place the HA outside of the test box (HA microphone is still active, so the test room should be quiet). Put FM transmitter/microphone in test box and set to OMNI MICROPHONE position. Evaluate FM response with 65 dB SPL input to the FM microphone (EFM/HA65_{SPL}). Record on worksheet.

7. Subtract HA (EHA/FM65_{SPL}) from FM (EFM/HA65_{SPL}) at the following 3 frequencies: 750, 1000 and 2000 Hz. Calculate a 3-frequency average of the differences. If the average difference is <+2 dB, do not change the FM setting. If the difference is >+2, change the FM setting as appropriate and re-evaluate EFM/HA65_{SPL} to confirm transparency. For example, if the FM average is 4 dB lower than the HA average, the FM setting should be increased by 4 dB and the average differences recalculated.

8. Perform a listening check with simultaneous inputs to FM and HA to judge overall signal quality and the relationship of the FM level to the hearing aid microphone.

9. For further assessment of appropriateness of FM fitting, proceed with validation procedures in Section 8 of the HAT guidelines (p. 14) and make adjustments in setting as needed. For example:
   - If validation results indicate difficulty hearing self—*decrease* FM level
   - If validation results indicate difficulty hearing others—*decrease* FM level
   - If validation results indicate distortion of main talker's voice or annoying increase in background noise when that person stops talking—*decrease* FM level
   - If validation results indicate difficulty hearing talker wearing the FM microphone—*increase* FM level.

SA1.7. Behavioral Verification Steps

SA1.7.1. Testing in Noise (See Figures SA1 and SA2)

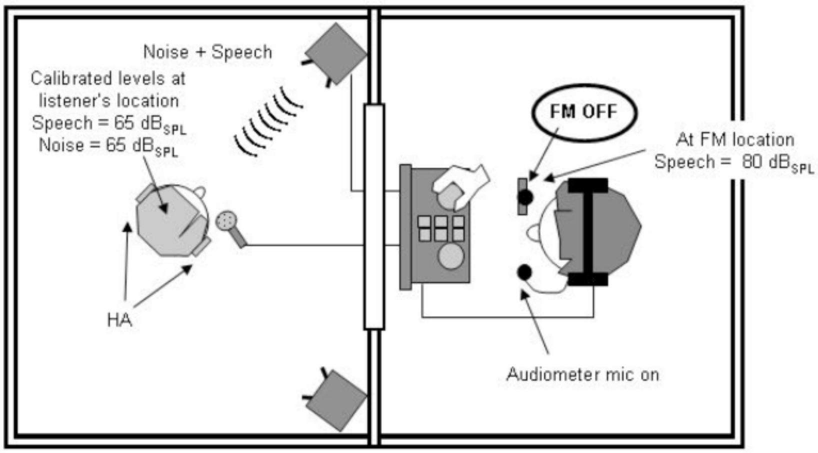
STEP 1. (Figures SA1a and SA2a) Evaluate performance for HA alone at 0 dB signal-to-noise ratio (BHA50/50HL)

- FM microphone on mute or OFF; FM receiver(s) on HA only or FM+M with microphone muted
- Student at 0 degrees azimuth to speaker presenting speech
- Speech presented at 50 dB HL (65 dB SPL) to represent typical level of teacher's voice in a classroom setting
- Noise presented at 50 dB HL to represent a 0 dB signal-to-noise ratio relationship.

STEP 2. (Figures SA1b and SA2b) Evaluate performance of FM + HA at 0 dB signal-to-noise ratio ($BFMHA50/50_{HL}$)

- Activate FM microphone
- Student remains in same test position
- Evaluate speech recognition performance with FM microphone ON or activated

a) Behavioral testing via hearing aid alone ($BHA65/65_{SPL}$)



b) Behavioral testing via hearing aids and FM ($BHA65/65FM80_{SPL}$)

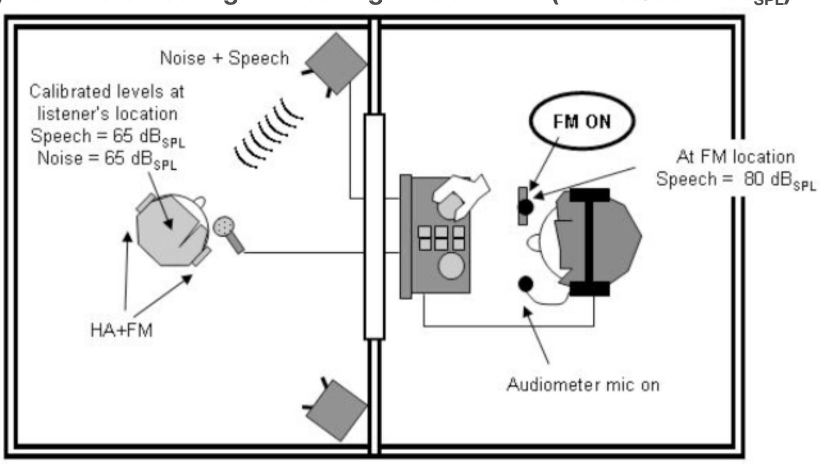
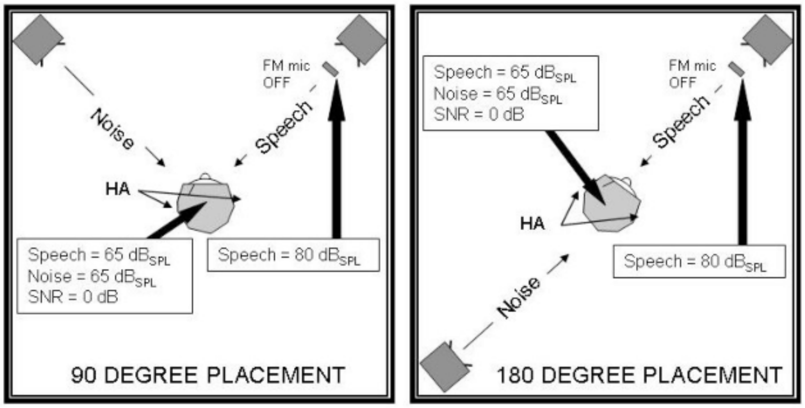


Figure SA1. Behavioral Test Configuration #1. FM microphone/transmitter worn on tester at typical distance (6 inches from mouth for lapel/lavalier; 1-3 inches from mouth for boom or check microphone). Based on ANSI S3.6-2004 (American National Standards Institute, 2004), Specifications for Audiometers, to convert SPL to HL subtract 15 dB.

a) Behavioral testing via hearing aid alone (BHA65/65_{SPL})



b) Behavioral testing via hearing aids and FM (BHA65/65FM80_{SPL})

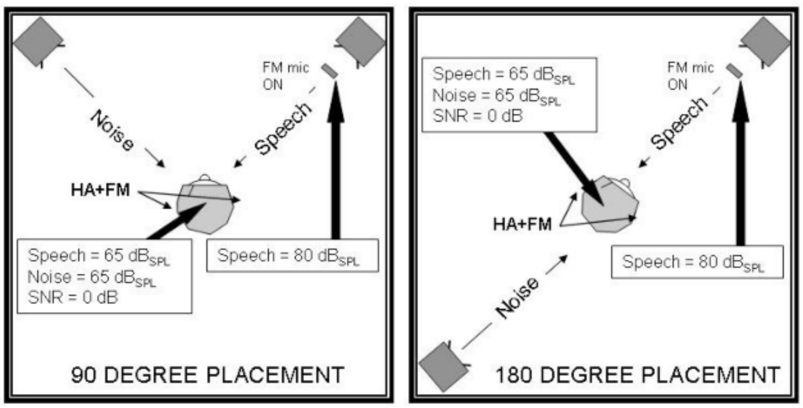


Figure SA2. Behavioral Test Configuration #2. FM microphone placed at calibrated test position (3-6 inches) in front of speaker presenting speech signal. Based on ANSI S3.6-2004 (American National Standards Institute, 2004), Specifications for Audiometers, to convert SPL to HL subtract 15 dB

Speech recognition performance with the FM in noise should be significantly improved over performance in noise with the HA alone. Speech recognition results from the FM in noise should be commensurate with speech recognition performance in ideal listening conditions.

SA1.7.2. Testing in Ideal Listening Conditions

STEP 1. Evaluate performance for HA alone in quiet (BHA50_{HL})

- FM microphone on mute or OFF; FM receiver(s) on HA only or FM+M with microphone muted;
- Student at 0 degrees azimuth to speaker presenting speech;

Speech presented at 50dB HL (approximately 65 dB SPL) to represent typical level of teacher's voice in a classroom setting.

STEP 2. Evaluate performance with FM + HA in quiet ($BFMHA50_{HL}$)

- Activate FM microphone;
- Student remains in same test position;
- Evaluate speech recognition performance with FM microphone ON or activated.

Configuration #1 (Figure SA1 minus noise) – FM microphone/transmitter worn on tester at typical distance (6 inches from mouth for lapel/lavalier; 1-3 inches from mouth for boom or check microphone).

Configuration #2 (Figure SA2 minus noise) – FM microphone placed at calibrated test position (3-6 inches) in front of speaker presenting speech signal

Speech recognition results in ideal listening conditions should be unchanged between the HA alone and with the FM active.

SA1.8. FM FITTING and VERIFICATION WORKSHEET: Hearing Aid

Name: ______________________________ Date of Birth: ____________________

Examiner: ______________________________ Date of Eval: ____________________

School District/Agency: ______________________ Default FM Channel: ______________

	Right Ear: HA	Left Ear: HA
Equipment Verification	Manufacturer:	Manufacturer:
	Model:	Model:
	Serial No:	Serial No:
	Use Settings:	Use Settings:
	FM receiver manufacturer & model:	FM receiver manufacturer & model:
	FM receiver Serial No:	FM receiver Serial No:
	Audio shoe:	Audio shoe:
	FM Program:	FM Program:
	FM transmitter manufacturer & model:	
	Transmitter serial number:	
	Type of microphone:	
Listening and Behavioral Check	☐ Listening check to HA alone ☐ Listening check for HA+FM signal ☐ Informal Behavioral check HA alone ☐ Informal Behavioral check HA+FM Comments:	☐ Listening check to HA alone ☐ Listening check for HA+FM signal ☐ Informal Behavioral check HA alone ☐ Informal Behavioral check HA+FM Comments:

Electroacoustic Evaluation

Initial FM Receiver Settings				
	750 Hz	1000 Hz	2000 Hz	Average
EFM/HA65$_{SPL}$ (FM setting ___)				
EHA/FM65$_{SPL}$				
Difference				

Adjusted FM Receiver Settings				
	750 Hz	1000 Hz	2000 Hz	Average
EFM/HA65$_{SPL}$ (FM setting ___)				
EHA/FM65$_{SPL}$				
Difference				

Formal Behavioral Check

Initial Noise Level		**FM Receiver Setting: ☐ FM ☐ FM+M**						
Condition		Speech dB HL	Noise dB HL	HA Settings	FM Settings	Speech List	# of Stimuli	Percent Correct
QUIET	BHA50$_{HL}$	50	None		Off			
	BFMHA50$_{HL}$	50	None					
NOISE	BHA50/50$_{HL}$	50	50		Off			
	BFMHA50/50$_{HL}$	50	50					

Adjusted Noise Level (if necessary)		**FM Receiver Setting: ☐ FM ☐ FM+M**						
Condition		Speech dB HL	Noise dB HL	HA Set-tings	FM Settings	Speech List	# of Stimuli	Percent Correct
NOISE	BHA50/__$_{HL}$	50			Off			
	BFMHA50/__$_{HL}$	50						
NOISE	BHA50/__$_{HL}$	50			Off			
	BFMHA50/__$_{HL}$	50						

Summary:

Note: FM=Frequency Modulated; HA=Hearing Aid; B=Behavioral

SA2. Group 2: Children and Youth with Cochlear Implants

All children with cochlear implants (CIs) who are educated in group settings are candidates for an FM system. Recent research has indicated that, on average, children with bilateral CIs and children with bimodal arrangements (CI and HA) obtain maximum benefit when using two FM receivers (Schafer & Thibodeau, 2006). However, not all children may demonstrate maximum benefit from these default arrangements and behavioral verification is imperative as part of a FM fitting for a CI user. A three-step protocol for verification of speech recognition benefit when using FM systems coupled to CIs is recommended. The first step is to verify the equipment is functioning and connected properly followed by informal and formal evaluation of speech recognition in noise with and without the FM system.

SA2.1. Pre-assessment Verification

Prior to use of an FM system with a cochlear implant, verify that the correct cords and connections have been obtained according to information provided by the manufacturer. It is also appropriate to investigate recommended processor and FM settings with both the cochlear implant and FM manufacturer. Because this often involves integration with other equipment either for that child or other devices in use in the school, an audiologist must be involved in the verification of FM used with CI.

Initially, all the user settings should be recorded as well as the program for FM use. It is also important to document the startup sequence relative to the on/off switches of the FM transmitter, FM receiver, and the CI. A sample FM/HA/CI Record Form is provided for this documentation and is located in 2.4.4.

SA2.2. FM Features

The basic features of FM systems are similar to those of hearing aids. FM transmitter features are reviewed in SA1.1. Only the receiver options will be reviewed in the following table.

FM Receiver Options for Cochlear Implants

Feature	Variations	Options	Pros	Cons
Type	Dedicated	FM Receiver works with a single CI model	Typically interfaces easily and securely within the CI case	Can only be used with one model resulting in costly upgrades
	Interchange-able	Receiver attaches to CI via adaptor or cable and can be used with more than one CI	Flexibility to use with other CI increases need to have backup equipment	Adaptor adds another part with the potential to malfunction
Connection of Interchangeable FM Receiver	Type	Adaptor at CI Base	May be easily removed when FM not in use	Adds length/weight to the CI May fall off
		Earhook	Doesn't add length to the CI	May need to be removed when FM not in use
		Cable	Doesn't add length to the CI	FM Receiver must be attached to clothing

Feature	Variations	Options	Pros	Cons
Channel	Number	Single Fixed	Easy for personal use – don't have to worry about changing channels	Less flexibility
		Multi-channel Selectable	Good for use in close proximity to other FM users (e.g. schools) Can be automatically changed to specific channel by transmitter	May be confusing for some users
Batteries	Type	Independent Battery	May increase battery life for CI use	Adds to troubleshooting
		Runs off CI Battery	No extra battery required	May decrease CI battery life
Programmable	Frequencies	Default Channel	Simplifies the startup for the user so that when turned on, correct channel is received	If transmitting situation changes, default may no longer be appropriate
		Channel Set	Reduces chance of inadvertently getting to wrong channel	Not as flexible if situation changes or equipment needed as backup
	FM/HA ratio	Adjust level of FM signal re: mic signal	Allows for customization of system for specific situations and user needs	May require PC to adjust settings
	Indicator Lights	Continuous or interrupted	May indicate reception of FM signal May indicate low battery function	May not give indication if battery exhausted May decrease battery life
Switches	Type	Automatic ON/FM	Less opportunity for user error	Cannot confirm setting visually
		Manual ON/FM	May aid in trouble-shooting	Possibility for user error re: turning on FM switch
	Mechanical	FM, FM+HA,HA	Can check settings visually	Requires manual dexterity Inadvertently changed

SA2.3. Informal Behavioral Verification Steps

Without the child/youth

1. Verify FM signal and CI mic signal through listening earphone if available for that CI model.
2. Verify the effect of rotating the sensitivity or volume control.
3. If listening check with FM/CI not possible, then verify the FM receiver function with a hearing aid or small external speaker.

With the child/youth

1. Present simple directions from in front of the child/youth.
2. If the child/youth wears bilateral CIs or CI plus HA, each side should be verified separately and then together
3. For each verification there are two steps:
   a. Confirm reception input from the local CI microphone by placing the FM transmitter and microphone far away and standing behind the child/youth to deliver simple commands.
   b. Confirm reception from the FM microphone by moving to the other side of the room with the FM transmitter and delivering simple commands from a distance through the FM microphone.

SA2.4. Formal Behavioral Verification Steps

For formal verification of the FM system with the CI, the behavioral protocol recommended in SA1.5. and SA1.7. for use with ear-level amplification is recommended. Because electroacoustic verification is not possible with cochlear implants, it is important to perform speech recognition testing with each FM receiver that is worn and then with the bilateral system. Speech recognition materials must be selected that have multiple, equivalent lists. The testing should be done first in ideal listening conditions followed by testing in noise.

SA2.4.1. Testing in Ideal Listening Conditions

STEP 1. Evaluate performance for CI alone in quiet ($BCI50_{HL}$)

- FM microphone on mute or OFF; FM receiver(s) on CI only or FM+M with microphone muted
- Speech presented at 50 dB HL approximately (65 dB SPL) to represent typical level of teacher's voice in a classroom setting

STEP 2. Evaluate performance with FM + CI in quiet ($BFMCI50_{HL}$)

- Activate FM microphone
- Student remains in same test position
- Evaluate speech recognition performance with FM microphone ON or activated

SA2.4.2. Testing in Noise

STEP 1. Evaluate performance for CI alone at 0 SNR ($BCI50/50_{HL}$)

- FM microphone on mute or OFF; FM receiver(s) on CI only or FM+M with microphone muted;
- Speech presented at 50 dB HL (65 dB SPL) to represent typical level of teacher's voice in a classroom setting.
- Noise presented at 50 dB HL to represent a 0 SNR (signal to noise ratio) relationship.

STEP 2. Evaluate performance with FM + CI in noise ($BFMCI50/50_{HL}$)

- Activate FM microphone;
- Student remains in same test position;
- Evaluate speech recognition performance with FM microphone ON or activated.

Speech recognition results in ideal listening conditions should be unchanged between the CI alone and with the FM active.

Speech recognition performance with the FM in noise should be significantly improved over performance in noise with the CI alone. Speech recognition results from the FM in noise should match speech recognition performance in ideal listening conditions.

Recommended Speech Levels: 50 dB HL (65 dB SPL) to represent the teacher's voice at a listening distance of 2 meters (Pearsons, Bennett, & Fidel, 1977). A variety of presentation levels could be considered to represent different listening distances, such as 55 dB HL (70 dB SPL) to represent the teacher's voice at a listening distance of 1 meter, or 40 dB HL (55 dB SPL) to represent conversational levels of speech from 2 meters.

Recommended Noise Levels: 50 dB HL (65 dB SPL) to represent average diffuse background noise levels in a classroom and a 0 signal-to-noise ratio. A +5 dB signal-to-noise ratio may be considered if the child's classroom environment warrants evaluation at a better signal-to-noise ratio.

SA2.5. FM FITTING and VERIFICATION WORKSHEET: Cochlear Implant

Name: ______________________________ Date of Birth: ____________________

Examiner: ______________________________ Date of Eval: ____________________

School District/Agency: ______________________ Default FM Channel: ______________

	Right Ear: CI or HA	Left Ear: CI or HA
Equipment Verification	Manufacturer:	Manufacturer:
	Model:	Model:
	Serial No:	Serial No:
	Use Settings:	Use Settings:
	FM receiver manufacturer & model:	FM receiver manufacturer & model:
	FM receiver Serial No:	FM receiver Serial No:
	Audio shoe/CI Adapter:	Audio shoe/CI Adapter:
	FM startup sequence:	FM startup sequence:
	FM transmitter manufacturer & model:	
	Transmitter serial number:	
	Type of microphone:	
Listening and Behavioral Check	☐ Listening check to HA/CI alone ☐ Listening check for FM signal ☐ Informal Behavioral check HA/CI alone ☐ Informal Behavioral check FM Comments:	☐ Listening check to HA/CI alone ☐ Listening check for FM signal ☐ Informal Behavioral check HA/CI alone ☐ Informal Behavioral check FM Comments:

Formal Behavioral Check

Initial Noise Level		**FM Receiver Setting: ☐ FM ☐ FM+M**						
Condition		Speech dB HL	Noise dB HL	HA Settings	FM Settings	Speech List	# of Stimuli	Percent Correct
QUIET	$BCI50_{HL}$	50	None		Off			
	$BFMCI50_{HL}$	50	None					
NOISE	$BCI50/50_{HL}$	50	50		Off			
	$BFMCI50/50_{HL}$	50	50					

Adjusted Noise Level (if necessary)		**FM Receiver Setting: ☐ FM ☐ FM+M**						
Condition		Speech dB HL	Noise dB HL	HA Settings	FM Settings	Speech List	# of Stimuli	Percent Correct
NOISE	$BCI50/\_\_{}_{HL}$	50			Off			
	$BFMCI50/\_\_{}_{HL}$	50						
NOISE	$BCI50/\_\_{}_{HL}$	50			Off			
	$BFMCI50/\_\_{}_{HL}$	50						

Summary:

Note: CI=Cochlear Implant; FM=Frequency Modulated; HA=Hearing Aid; B=Behavioral

SA3. Group 3: Children and Youth with normal hearing sensitivity who have special listening requirements

As stated previously in this document, there is no specific default arrangement for children/youth with normal hearing sensitivity that have special listening requirements. This supplement deals with ear-level FM. Therefore, this section provides behavioral and real-ear verification procedures for fitting ear-level FM-only systems. Information regarding other fitting options will be provided in additional supplements.

SA3.1. Ear-level FM Transmitter Features

FM transmitter features are reviewed in SA1.1. Only the receiver options will be listed below.

SA3.2. Ear-level FM-only Receiver Features

- Multi-channel selectable (216-217 MHz range only)
- Default Channel programmable
- Max output range is programmable
- User adjustable volume/gain control
- Zinc air batteries

Does not have:

- Local microphone
- HA interface
- Indicator lights

SA3.3. Ear-level FM-only Verification Procedures

The ear-level FM-only fitting is most often an open-canal configuration. When using ear-level FM-only devices on normal-hearing children, real-ear measures are advised. Typical electroacoustic measures using a 2cc coupler are not recommended as they do not account for the acoustics of an open-canal fitting. The goal of verification procedures with ear-level FM-only devices is to confirm consistent audibility of the FM signal. This is achieved by using input levels and stimuli that closely approximate typical use conditions.

SA3.3.1. Verification Terminology (see SA1.3.1)

SA3.3.2. Verification Priorities

Under normal conditions of use, the FM system should maintain comfort and audibility of a close speech input (1–6” from talker’s mouth)

It is advisable to assess real-ear performance with a speech-weighted input

Maximum output should be assessed in the real ear. This is especially important given that most FM-only users will have normal or near-normal hearing.

Speech perception measures with FM can be completed as a behavioral verification option, with priority given to testing in noise.

SA3.4. Real Ear Verification

A variety of real-ear test equipment is available to evaluate ear-level FM-only systems. Some real-ear verification systems have FM-specific test protocols incorporated in their software. With some systems the FM microphone is placed inside the sound chamber for real-ear measures of FM. Other systems require that the FM microphone be placed in the calibrated position in the sound field for real-ear verification. Step-by-step procedures will differ depending on the type of real-ear test system available.

SA3.4.1 Open-canal verification issues

A number of issues specific to ear-level FM-only devices must be addressed when verifying these systems. First, because of the open-canal coupling, sound will enter the ear via 2 paths: direct and amplified.

The *direct* sound path consists of sounds entering the canal around the transducer or open earmold coupling (Hoover, Stelmachowicz, & Lewis, 2000; Kopun, Stelmachowicz, Carney, & Schulte, 1992) and will vary in level depending on distance of the sound source from the listener. This can include unamplified portions of the voice of the person wearing the FM microphone, other talkers and background noise, as well as the user's own voice.

Amplified sound enters the ear canal from the FM receiver(s). The input level of the amplified signal is more consistent and depends on the close distance of the FM microphone from the talker or from auxiliary inputs into the transmitter. However, because of the open canal configuration, most of the lower frequency portions of the signal will "leak" out of the open canal (Hoover, et al., 2000).

A second issue relates to using conventional hearing aid verification systems to confirm performance of an ear-level FM-only device. Current systems have one of two options available to assess real-ear FM performance. In both cases there are difficulties in assessing both direct and amplified inputs:

> **Option 1:** The FM microphone is placed in the test box and the real-ear microphone is placed in the student's ear. The reference microphone is active in the sound chamber, not in the sound field. In this condition there is no direct (unamplified) signal available.
>
> **Option 2:** The FM microphone is placed outside the test box in the calibrated position in the sound field. The real-ear microphone is placed in the student's ear and the reference microphone is de-activated. In this condition, it is difficult to place both the FM microphone and user (child/youth) at an appropriate distance from each other and from the sound field loudspeaker. The level of the direct signal may be compromised if the student cannot be moved a significant distance from the loudspeaker.

SA3.5. Behavioral Verification (see SA1.5. and SA1.7.)

Procedures for behavioral verification of ear-level FM-only systems are essentially unchanged from procedures illustrated in SA1.7. with the exception that hearing aid only testing is replaced by unaided testing in noise.

SA3.6. Real-Ear Verification Steps

Procedures will differ depending on the type of real-ear equipment used:

SA3.6.1. Real-Ear Verification with the FM microphone placed in the sound chamber (Option 1)

1. Select FM as the instrument.
2. Complete real-ear saturation response measures at maximum volume setting. A constant-level swept pure-tone signal is recommended, using the highest SPL output available from the test system (85 or 90 dB SPL). Adjust receiver settings as needed to meet targets based on audiometric thresholds.
3. Complete real-ear measures at use settings (start at ½ volume) and adjust gain/volume to achieve peak outputs that match targets in the 1000-4000 Hz range. FM input levels are chosen to correspond with the type of FM microphone used (80-85 dB SPL for a chest-level microphone, 90-95 dB SPL for a boom microphone). Calibrated real speech signals are preferred, but speech-weighted signals are also recommended.
4. Once targets have been met, repeat real-ear saturation response measure at use setting.

SA3.6.2 Real-Ear Verification with the FM microphone placed at the calibrated position in the sound field (Option 2)

1. With the child in front of the sound field loudspeaker, calibrate the sound field
2. Measure an ear-canal resonance with a 75 dB SPL speech-weighted input.
3. Deactivate the real-ear system's reference microphone. Move the child away from the microphone/transmitter and place FM microphone in the calibrated position.
4. Complete real-ear saturation response measures at maximum volume setting. A constant-level swept pure-tone signal is recommended, using the highest SPL output available from the test system (85 or 90 dB SPL). Adjust as needed to meet targets.
5. Complete a real-ear measure at use settings (start at ½ volume) with an 85 dB SPL speech weighted input and adjust the gain/volume so that the peaks match the ear-canal resonance for the frequencies 1000-4000 Hz (i.e., unity gain/transparency).
6. Once targets have been met, repeat saturation response measure at use setting.

SA3.7. FM FITTING and VERIFICATION WORKSHEET: FM Only

Name: ______________________________ Date of Birth: ____________________

Examiner: ______________________________ Date of Eval: ____________________

School District/Agency: ______________________ Default FM Channel: ______________

	Right Ear: FM	Left Ear: FM
Equipment Verification	Manufacturer:	Manufacturer:
	FM Receiver Model:	FM Receiver Model:
	Serial No:	Serial No:
	Use Settings:	Use Settings:
	FM Transmitter Manufacturer & Model:	
	Transmitter Serial Number:	
	Type of microphone:	
Listening and Behavioral Check	☐ Listening check to FM signal ☐ Informal Behavioral check FM Comments:	☐ Listening check to FM signal ☐ Informal Behavioral check FM Comments:

Real-Ear Evaluation (See verification steps for details)

OPTION 1: FM Microphone in Sound Chamber

☐ Real-ear saturation response

☐ Real-ear measure at use settings

☐ Repeat real-ear saturation response, as needed

☐ Attach real-ear measures to this form

OPTION 2: FM microphone in Calibrated Position in Sound Field

☐ Measure ear canal resonance

☐ Real-ear saturation response

☐ Real-ear measure at use settings

☐ Repeat real-ear saturation response, as needed

☐ Attach real-ear measures to this form

Formal Behavioral Check

Initial Noise Level								
Condition		Speech dB HL	Noise dB HL	HA Settings	FM Settings	Speech List	# of Stimuli	Percent Correct
QUIET	$B50_{HL}$	50	None		Off			
	$BFM50_{HL}$	50	None					
NOISE	$B50/50_{HL}$	50	50		Off			
	$BFM50/50_{HL}$	50	50					

Adjusted Noise Level (if necessary)								
Condition		Speech dB HL	Noise dB HL	HA Set-tings	FM Settings	Speech List	# of Stimuli	Percent Correct
NOISE	$B50/\_\_{}_{HL}$	50			Off			
	$BFM50/\_\_{}_{HL}$	50						
NOISE	$B50/\_\_{}_{HL}$	50			Off			
	$BFM50/\_\_{}_{HL}$	50						

Summary:

Note: FM=Frequency Modulated; HA=Hearing Aid; B=Behavioral

SA4. Quick Reference Summary of Evaluation Steps for Verification of Ear-Level FM Systems

ELECTROACOUSTIC EVALUATION STEPS					
Step	Abbreviation	What's in the Test Box?	What's out of the Test Box?	What kind of signal?	What is the signal level? (dB SPL)
1	$EHA65_{SPL}$	Hearing aid alone	NA	Calibrated Real Speech or Composite Digital Noise	65
2	$EHA/FM65_{SPL}$	Hearing aid + FM Receiver set to FM+ENV	FM microphone with FM Transmitter ON	Calibrated Real Speech or Composite Digital Noise	65
3	$EFM/HA65_{SPL}$	FM microphone with FM Transmitter ON	Hearing aid + FM Receiver set to FM+ENV	Calibrated Real Speech or Composite Digital Noise	65

BEHAVIORAL EVALUATION STEPS (For cochlear implant, substitute CI for hearing aid below)					
Step	Abbreviation	What's on the child?	What's on the examiner?	What is the Speech level? (dB HL)	What is the Noise level? (dB HL)
1	$BHA50/50_{HL}$	Hearing Aid	FM Transmitter Turned OFF	50	50
2	$BFMHA50/50_{HL}$	Hearing Aid + FM	FM Transmitter Turned ON	50	50
3	$BHA50_{HL}$	Hearing Aid	FM Transmitter Turned OFF	50	OFF
4	$BFMHA50_{HL}$	Hearing Aid + FM	FM Transmitter Turned ON	50	OFF

REAL EAR EVALUATION STEPS					
Step	Abbreviation	What's on the child?	What's receiving the signal?	What kind of signal?	What is the signal level? (dB SPL)
1	$REAC75_{SPL}$	No Instruments	Open Ear Canal	Calibrated Real Speech or Composite Digital Noise	75
2	$RFM90_{SPL}$	FM Receiver at Max Setting	FM Transmitter	Pure Tone	90
3	$RFM85_{SPL}$	FM Receiver at User Setting	FM Transmitter	Calibrated Real Speech or Composite Digital Noise	85

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