American Academy of Audiology
Clinical Practice Guidelines

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

Supplement B: Classroom Audio Distribution Systems—Selection and Verification

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Contents

[1] This document is a supplement to the core document, *AAA Clinical Practice Guidelines for Remote Microphone Hearing Assistance Technologies for Children and Youth from Birth-21 Years.*

1. INTRODUCTION AND RATIONALE

1.1. Definition

A 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).*

1.2. Rationale

Classroom ADSs may be necessary to ensure an audible and consistent distribution of the talker's voice throughout a classroom or learning space. Such systems may assist all students but may be particularly useful for those with hearing and listening problems. These systems may also improve the audibility of talkers (e.g., teachers and students) with low amplitude voice levels. Systems may be designed for an entire classroom or a targeted area (e.g., a small group or for an individual (such as desktop placement).

Classroom ADSs serve to maintain a consistent speech-to-noise ratio (SNR) to overcome the effects of loud noise sources such as ventilation systems. They are not a substitute for inadequate acoustical treatment of the learning environment.

2. PRE-REQUISITE CONSIDERATIONS

2.1. Room Acoustics

The performance of a classroom ADS, regardless of the manufacturer or principal methods of sound distribution, is contingent upon the acoustical properties of the classroom for optimal performance. The background noise levels present (whether internally or externally generated), as well as the reverberation times at given frequencies may negatively impact the goals of signal distribution: audibility, intelligibility, and a comfortable listening level that is evenly distributed throughout the classroom. The ANSI/ASA S12.60-2009/2010 provides recommendations for appropriate measurements.

The ANSI/ASA S12.2-2008 Criteria for Evaluating Room Noise should be considered an appropriate reference for assessing room acoustics. However, the procedural methods and instrumentation are likely beyond the scope of professionals other than acoustical engineers or consultants. Alternatively a guided, subjective assessment of the acoustical properties of the room may be utilized. This supplement therefore proposes a three-tiered approach to classroom acoustical analysis: 1) Subjective acoustical screening; 2) Basic measurements of noise and reverberation using instrumentation; and 3) Referral for acoustical analysis by an acoustical consultant. *A Classroom Acoustical Screening Survey Worksheet* is located in Appendix 7.1 that details the procedures described below.

2.1.1. Tier 1. Subjective Acoustical Screening

This type of acoustical analysis is a cursory "listening assessment" using a checklist to note obvious problems that might negatively impact the performance of a classroom ADS.

2.1.2. Tier 2. Basic Measurements of Noise and Reverberation

When a concern is identified in the Tier 1 Subjective Acoustical Screening, measurement of background noise and/or reverberation is warranted. Guidelines for optimal classroom acoustics are well documented (ANSI S12.60-2009/2010, American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools and Part 2: Relocatable Classroom Factors). Units of measurement of background noise are typically noted in dB A-weighted, with reverberation measured in RT60 (the amount of time for a signal to decay by 60 dB).

A Type II sound level meter capable of measuring noise levels to 35 dB A or less is required for noise measurements. RT60 values may be estimated using the Sabine formula or obtained using reverberation instrumentation with simple signal generation material (e.g., balloon). See Appendix 7.1, Parts 2 and 3 of the *Classroom Acoustical Screening Survey Worksheet* to record and calculate measurements.

Of interest is the emergence of software applications for mobile phones and other handheld electronic devices that have the potential to provide fast, accurate and affordable acoustical information. Budgetary constraints should not preclude the ability to conduct basic acoustical analyses in the classroom.

2.1.3. Tier 3. Referral for Further Acoustical Analysis

Some classrooms may have excessive noise levels, excessive reverberation times, or both. Basic measurements may show that noise levels and/or RT60 are outside acceptable limits. Consultation with an acoustical engineer is an appropriate next step to investigate additional acoustical measures, as well as mitigation strategies that might be implemented prior to the installation of a classroom ADS. Installing passive sound absorbing materials, decoupling HVAC systems from ceilings or walls, modifying ductwork and venting, all fall outside the scope of practice of the audiologist. However, providing the acoustical consultant with Tier 1 and 2 information in an articulate, thoughtful manner can expedite the mitigation process, as well as help reduce associated costs to the school district.

2.2. Compatibility With Personal FM systems

Classroom ADSs and personal FM systems both can be beneficial to students, and sometimes are used simultaneously in the same classroom. The teacher may wear a microphone/transmitter for each system at the same time (Figure 1). A parallel method of signal transmission is preferred because it preserves the electroacoustic characteristics of the FM signal through the personal FM receiver(s) worn by the student(s) and also to the classroom ADS. In parallel processing, the personal FM receiver(s) and the classroom ADS receive and process the signal independently of one another.

As an alternative, the teacher may wear just one microphone/transmitter. In this sequential method of transmission, it is recommended that the teacher wear the FM transmitter and the signal be delivered to the classroom ADS via a dedicated FM receiver connected to the input of the ADS amplifier as shown in Figure 2. Although this sequential method still allows for an optimal signal for the student with a personal FM receiver, possible electroacoustic variations in the classroom ADS signal make it a less desirable option than parallel processing.

It is also possible for one system to incorporate parallel processing in a single microphone/transmitter, providing a signal(s) directly to both the personal FM receiver(s) worn by the student(s) and to the classroom ADS. Thus, the personal FM receiver(s) and the classroom ADSs receive and process the signal independently of one another even though one microphone is being used. In the future, continued technological advances should provide additional options for maximizing the signal from both the classroom ADS and the personal FM system.

Regardless of the arrangement, to address compatibility of both a classroom ADS and personal FM systems in the classroom the audiologist must address the following:

- Does one system ever interfere with the other, and under what circumstances?
- After initial compatibility in sequential use is accomplished, do subsequent adjustments to the first system to optimize its performance inadvertently degrade the performance of the second system?
- With either a parallel or sequential configuration, what arrangement of the two systems is easiest and least time-consuming for the teacher to manage while allowing each system to fully provide its intended benefit?

Answers to these questions will help determine how classroom ADSs and personal FM systems can be used appropriately together in the same classroom.

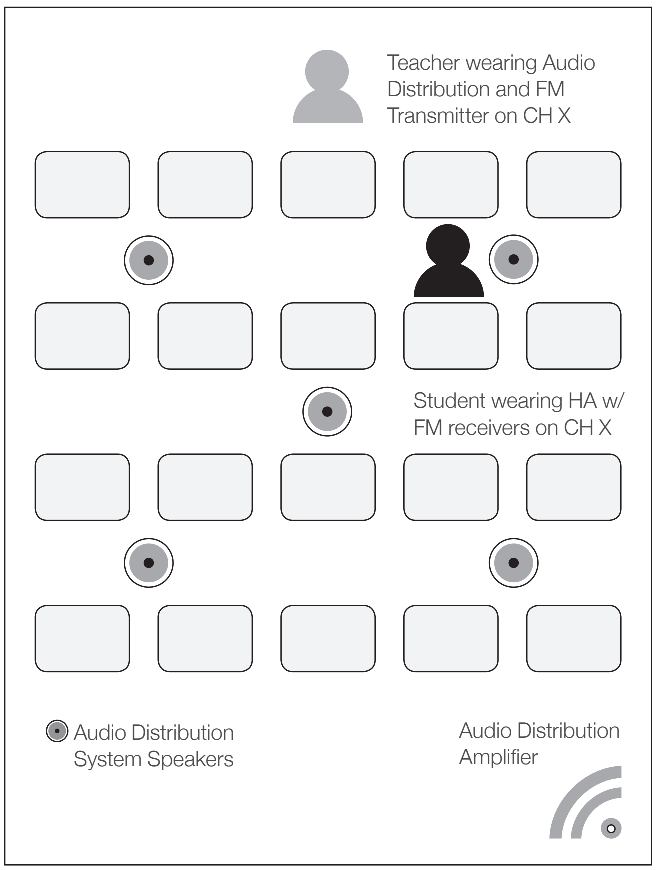

Figure 1. Parallel arrangement where teacher wears two microphones.

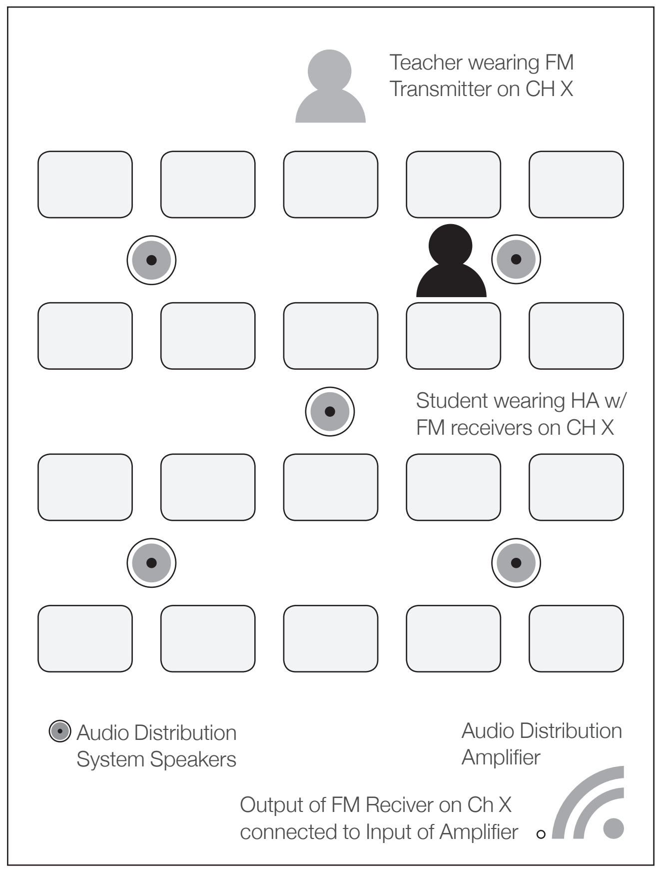

Figure 2. Sequential arrangement where teacher wears one microphone and the signal is transmitted to a receiver that is attached to the input of the audio distribution amplifier.

3. SELECTION CONSIDERATIONS

3.1. Transmitter Options

FM radio, infrared light (IR) and other signal transmission options may be available or employed. Transmitters are generally pendant-style microphone/transmitter units that do not require a separate microphone and interface cable. Lapel microphones that are coupled to separate transmitter units are also frequently used. Head or boom microphones coupled with the transmitters are an option used to further enhance signal clarity. Some transmitters provide a direct input port to receive and transmit input from other media sources. Transmitters may include audio output level manipulation as well. In these instances, the output level from the transmitter may be controlled by the user, or there may be circuitry within the unit that adjusts the audio output level automatically. Both options are designed to help maintain an optimal signal-to-noise ratio throughout the classroom.

Additionally, data logging capabilities may be employed to store/retrieve total use time and other performance parameters that may be of interest to monitor the use of the system. Signal transmission/reception system technologies are rapidly evolving and additional options other than those described here may be available.

3.2. Receiver Options

Typical classroom ADSs (those that have been designed to provide a signal throughout the entire room) employ a "base-type" receiver/amplifier. Level and frequency controls may be provided in these units. The receiver not only routes the transmitter signal, but may include input capability for other sources such as computers, DVD players, and other streaming media sources. In some cases, remote sensors, mounted in a location separate from the base, pick up the transmitted signal, routing the signal to the base via hardwire.

3.3. Loudspeaker Options

There are many loudspeaker designs and configurations that can be used in classroom ADSs. The installation criteria common to all of the designs are to (1) improve the signal-to-noise ratio evenly throughout the classroom, (2) enhance the level of the signal without drawing attention to the signal as being amplified and (3) produce a signal that does not exacerbate undesirable classroom acoustics, especially reverberation. These installation criteria can be attained with properly installed traditional loudspeakers or by the use of new loudspeaker technologies.

3.4. Individual Listener Requirement Considerations

The current guidelines are designed to meet the acoustical listening needs of three groups of children and youth. This supplement modifies those original groups because all children in classrooms are impacted by the implementation of classroom ADSs. Thus, for the purpose of this supplement, the targeted listening groups include:

- Group 1: Children and youth with no special listening requirements
- Group 2: Children and youth with hearing loss using hearing aid(s)/cochlear implant(s)/bone anchored hearing device who may be using a personal FM
- Group 3: Children and youth with normal hearing sensitivity that have special listening requirements and may be using a personal FM.

While the default fitting arrangements for children/youth in Group 2 specify bilateral, ear-level, wireless technology, these HAT Guidelines address possible contraindications to the default arrangement. In some of those instances, it may be more appropriate to utilize a classroom ADS. There is no default fitting arrangement for children/youth in Groups 1 and 3. Again, there will be numerous instances when a classroom ADS (whole room or targeted area) is the most appropriate fitting arrangement for these groups of children. See section 5.3.1 of the core section of this HAT guideline for a discussion of audiological considerations that should be addressed when implementing remote microphone HAT for an individual child/youth.

Another important factor to be addressed when considering a remote microphone HAT for an individual child/youth is the listening environment where improved communication access is needed (see Sections 5.3.3 of the core section of the guideline for a detailed discussion listening environment considerations in school settings). Some environments are more appropriate for classroom ADSs than others. In addition, there will be some environments where a large-area system is needed and others where a targeted-area system is a better choice.

Prior to use of classroom ADSs, both audiological and listening environment considerations should be addressed with input from the audiologist, school personnel, student and family. Doing so is important for successful implementation.

4. SET-UP PROCEDURES

4.1. Loudspeaker Placement

Placement of the loudspeaker(s), or acoustic transducer(s), varies depending on the transducer technology utilized. Currently, loudspeakers and their placement may consist of traditional cone loudspeakers placed in the ceiling of the enclosure; flat panel or forced resonance transducers that may be ceiling, wall or stand mounted; or columnar loudspeaker arrays that produce a cylindrical wave front that may be placed in various locations in the room. All are typically placed at or above the ear level of the listener. Knowing the approximate critical distance[1] of the room is important for proper loudspeaker placement. It is desirable to place the loudspeaker(s) such that the direct energy from the loudspeaker is forming its own direct signal radiating field separate from the direct signal emanating from the teacher's own *unamplified* voice. In other words, it is desirable to have multiple direct sound sources that allow groups of listeners to be receiving a signal from one of those sources, as opposed to a reflected source. There is no advantage to placing the loudspeaker near the individual using the microphone as both signals reach the same critical distance. To achieve distributed audio in the classroom, it is necessary to place loudspeakers in the optimum location(s) according to manufacturer's recommendations. Simply placing wall-mounted loudspeakers on the teaching wall in the front of the classroom rarely achieves the goals of distributed audio and critical distance. While the benefits of listening within a critical distance are well established, further research is needed to establish potentially greater benefits of listening at shorter distances.

4.2. Intensity Levels

The ANSI S12.6-2002 standard for Acoustical Performance Criteria in Learning Environments, recommended a signal-to-noise ratio (SNR) for core learning spaces of at least +15 dB. This SNR should be achievable by ensuring that the unoccupied noise is level is approximately 35 dBA, and the reverberation time is approximately 0.6 seconds. It might be assumed that the level of the audio signal produced by classroom ADSs should therefore simply be 15 dB above the noise floor. This theory is misleading however, as the unamplified direct and reverberant sound pressure level of the individual talking must be taken into consideration. In addition, efforts to mitigate excessive background noise levels and reverberation times should be completed in order to maximize the overall SNR improvement provided by the classroom

[1] Critical Distance may be described as the approximate distance from the direct sound source at which the sound pressure level from this source is equal to the reverberant sound pressure level occurring from reflected sound energy in the room. As reverberation time in the classroom increases, critical distance decreases. Therefore, minimizing reverberation time in the classroom maximizes critical distance and improves access to the signal from the direct sound source. Please see Appendix 7.1 for more information.

ADS. In an occupied classroom, assuming that the unamplified sound pressure level of the teacher's voice is 65 dBA measured at a distance of one meter, a distributed signal should essentially maintain that approximate level as measured at several locations in the room. The goal of the classroom ADS is to distribute the desired signal evenly throughout the classroom, not to "amplify" the signal in the way that a public address system amplifies a signal. The ANSI performance criteria described above can best be met by a combination of physical room modifications and the use of audio distribution technologies. Further research in the area of optimal signal level of classroom ADSs is needed.

4.3. Frequency Response

Of particular significance in addressing the issue of "loudness" of classroom ADSs is differentiating between the concepts of audibility vs. intelligibility. The loudness level of a system is generally associated with its audibility level – frequencies at or below 1 kHz. While varying the level of the system to ensure comfortable audibility is desirable, sacrificing the high frequency information responsible for good intelligibility is not. This can be especially difficult in highly reverberant rooms where low frequencies are unable to be dissipated rapidly enough for perception of high frequency consonant phonemes. Consideration of both audibility and intelligibility is therefore essential in setting the loudness level of the system. (See "Behavioral Verification Procedures, 5.2.4.)

4.4. Feedback

Feedback in classroom ADSs is similar to the feedback that occurs in personal hearing instruments. The system's output signal becomes re-amplified, resulting in "squealing" or other undesirable distortions of the original source. Feedback may result from the microphone/transmitter being in close proximity to the output transducer(s). Maintaining an appropriate distance between the microphone/transmitter and the output transducer(s) generally mitigates feedback problems. However, feedback suppression circuitry, or manipulation of equalization circuitry as directed by the system manufacturer may be employed. Simply reducing the overall output level of the system is not recommended, as doing so would obviously impact the efficacy of the system.

5. AUDIO DISTRIBUTION SYSTEM VERIFICATION PROCEDURES

5.1. Group 1: Children and Youth With No Special Listening Requirements

5.1.1. "Real Room" Verification Procedures

Initially, a listening check for clarity of speech should be performed while the teacher is speaking in an unoccupied classroom with typical vocal effort. Adjustments of equalizers may be performed to accomplish optimum signal clarity as judged by an adult with normal hearing. Measurement of the classroom ADS signal levels may be performed according to Appendix 7.1, *Classroom Acoustical Screening Survey Worksheet*.

5.1.2. Reverberation Time Verification Procedures

See Appendix 7.1, Classroom Acoustical Screening Survey Worksheet, Part 3, Reverberation Time

5.1.3. Behavioral Verification Procedures

If it is deemed necessary to provide evidence of classroom ADS benefit, speech recognition testing can be performed as outlined in section 5.2.4 after students' acclimatization to use of the system. Appendix 7.2, *Classroom Behavioral Verification/Validation Worksheet for Personal FM and Audio Distribution System (ADS) Use*, may be used.

5.2. Group 2: Children and Youth with Hearing Loss Using a Hearing Aid(s)/Cochlear Implant(s)/Bone-Conduction Hearing Device Who May be Using a Personal FM System

5.2.1. "Real Room" Verification Procedures-See 5.1.1.

5.2.2. Reverberation Time Verification Procedures- See 5.1.2.

5.2.3. Coupled Classroom ADS and Personal FM Verification

Because of potential undesirable variation when interfacing a classroom ADS and personal FM system, the connection of the personal FM transmitter to the audio output of the ADS is not recommended (sequential signal processing). The teacher should wear two microphones, one for the personal FM receivers(s) and one for the classroom ADS (parallel signal processing). Alternatively, the teacher may wear a transmitter that directly serves, both the personal FM receivers(s) worn by the student(s) and an FM receiver that provides input to the classroom ADS (parallel signal processing). Electroacoustic verification of personal FM benefit should be performed for each arrangement according to this HAT Guideline core document. Verification of classroom ADSs can proceed as outlined in Section 5.1.1.

5.2.4. Behavioral Verification Procedures (see Appendix 7.2, *Classroom Behavioral Verification/ Validation Worksheet for Personal FM and Classroom Audio Distribution System (ADS) Use*

Classroom Acoustics: Identify potentially problematic noise and reverberation sources that may be impacting classroom listening and learning.

Informal Behavioral Check: Perform a listening check of each student's personal hearing instruments and the classroom ADS system to determine that all systems are functioning properly. Conduct a behavioral check of each student with their personal hearing instruments alone followed by another behavioral check with their personal FM systems turned on to verify that the student is receiving the intended inputs. For, example, the student may be asked to repeat the Ling Six-sounds (Ling, 1976) for this informal behavioral check.

Equipment Verification: If the child is using a personal FM system, then verification may be performed according to recommended procedures in Supplement A of these HAT Guidelines. If a personal FM system is not used, then formal behavioral verification in the actual classroom may be performed with the classroom ADS

Formal Behavioral Evaluation: Age-appropriate speech perception materials, preferably sentences, should be presented in the typical listening arrangement in the occupied classroom, without visual cues with and without the classroom ADS. The use of written responses may allow the entire class of students to participate. Percent correct results with and without the classroom ADS may be compared to determine benefit.

5.2.5. Validation Procedures

Procedures should be performed in the classroom with and without the classroom ADS. A protocol such as the Listening Inventory for Education (L.I.F.E.) (Anderson & Smaldino, 1997) may be used to complete the Appendix 7.2 Worksheet, *Classroom Behavioral Verification/Validation Worksheet for Personal FM and Classroom Audio Distribution System (ADS) Use*). Additional validation instruments are located in Appendix D of the core HAT Guideline. Begin the validation process by 1) familiarizing the teacher with behaviors addressed in the validation worksheet; 2) one week later and before classroom ADS is used, have the teacher and/or student (if age/competency appropriate) complete the validation form; 3) after a week of full-time use of classroom ADS, ask teacher and/or student to complete validation form; 4) compare before/after responses. If the comparison of responses indicates adjustments to the system are necessary, make the adjustments and repeat the validation process.

5.3. Group 3: Children and Youth with Normal Hearing Sensitivity Who Have Special Listening Requirements and May Be Using a Personal FM – See procedures in 5.2.

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APPENDIX 7.1

Classroom Acoustical Screening Survey Worksheet[2]

Directions

This worksheet contains a tiered approach to surveying classroom noise levels and reverberation times that can be used by professionals with varying degrees of training and equipment. The purpose of the worksheet is to help identify classrooms that may have acoustical problems that interfere with communication and instruction. These problems affect a student's ability to attend, hear, listen, understand and participate in educational programs. They will also detract from the performance of a classroom audio distribution system (ADS) that might be in use. Section 1 (Tier 1) is a cursory listening assessment using a checklist to note obvious problems that might negatively impact the performance of a classroom ADS. Sections 2-4 require more knowledge and training to take measurements or estimate levels. When noise and/or reverberation levels are suspected as exceeding those recommended by ANSI/ASA S12.60-2009/2010, the screening survey data is an indicator for further assessment. This assessment may include a referral to an acoustical specialist who can perform a comprehensive acoustical analysis and suggest solutions.

Directions for Classroom Observations (Section 1 of the Worksheet)

Complete the checklists for background noise levels and reverberation times. Any "yes" responses are indicators of possible problems and a referral to Tier 2 measurements that are contained in Sections 2-4 of this worksheet. Provide information regarding current technology used in the classroom, teacher to listener distance, classroom and instructional style, and seating arrangements.

Directions for Classroom Sound Level Measurements (Section 2 of the Worksheet)

Equipment needed: Type II sound level meter (SLM), 20 ft measuring tape or laser tape, standard reading material (e.g., rainbow passage or similar sustained reading material).

1. Draw a schematic of the classroom on the back of the form or a separate piece of paper marking the locations of the measurements (A-F). Generally measurements should be taken from student desks at the four corners of the instructional area, the middle and the middle back of the room. If there is a target student, use location A to mark that student's position and eliminate middle back of room. Additional positions can be added if necessary.

2. Identify the make and model of the SLM used as well as the averaging timeframe. The ANSI/ASA S12.60-2009/2010standard requires a one hour average of the noisiest time period during learning instruction to capture maximum internal (inside the classroom) as well as external (outside the classroom and building) noise. When it is not possible to perform a one hour average, indicate, under the short term option, the number of seconds or minutes and the number of time samples that were made to determine the average for each measurement (e.g., 5 time samples, 1 min each). Type II SLMs may contain an averaging function to determine this value and often recommend a timeframe.

3. Weighting: Ideally, sound level measurements should be taken in both A- and C- weighted conditions for the classroom ambient noise levels. A-weighting will capture a better estimate of speech information as received by the listener while the C- weighting will address HVAC and other low frequency noise in the classroom. If only one weighting is performed, select A- weighted. Only A- weighted levels are used to measure the teacher's voice levels to determine the speech-to-noise ratio (SNR) level.

[2] *Source:* Adapted by C. D. Johnson & J. Smaldino (2010) from Acoustic measurements in classrooms by J. Smaldino, C. Crandell, & B. Kreisman, 2005. In *Sound Field Amplification,* Crandell, Smaldino, & Flexer (Eds.) p. 131. Thomson Delmar Learning. Reprinted by permission.

4. Ambient Noise Levels:

   a. Turn on the SLM; set to the A- or C-weighted scale and slow response. If you can set the range of the meter, set it to accommodate 40-60 dB SPL to begin.

   b. Ambient noise levels should be measured for the unoccupied and occupied conditions at several locations in the classroom as levels may vary according to distance from noise sources. Indicate which condition you are using by circling the corresponding number (1=unoccupied, HVAC off; 2=unoccupied, HVAC on; 3=occupied, HVAC off; 4=occupied, HVAC on); use the column that corresponds to the weighting used for each of the measurements taken. Measure as many conditions as possible. When making short-term measurements, it is recommended that 3 to 5 one-minute time samples are averaged to determine the level. *The ANSI/ASA S12.60-2009/2010standard is based on a one hour average unoccupied classroom with the HVAC on; therefore a measurement in this condition is necessary when making a comparison to the standard.*

   c. If the room is occupied, have the students remain quiet. Measure the ambient noise level at the selected student locations and record it on the worksheet. These measurements will provide an estimate of the ambient noise level during an instructional period. If measurements can only be taken in an empty classroom you may estimate occupied classroom levels by converting the unoccupied noise levels to occupied by adding 10 dB to each unoccupied measurement. This conversion is comparable to reported differences in noise levels between *average* unoccupied and occupied classrooms (Bess et al., 1984; Bradley & Sato, 2008; Sanders, 1965).

   d. Calculate and record the average ambient noise level for each condition measured. Compare to the ANSI/ASA S12.60-2009/2010standards for the weighting used and the size and type of room (permanent or portable).

5. Teacher Voice Levels:

   a. Position the teacher in the typical instructional position in the classroom. The students should be seated in their normal locations for instruction. It is important that the measurements are made at a time that represents the noisiest time of instruction, especially if there is significant external noise. This procedure will help capture the acoustical conditions that represent the average maximum noise periods of the day.

   b. Set the SLM for A-weighted measurements. Orient the SLM to approximate the center of each selected student's positions while he/she is seated at his/her desks. Point the SLM toward the teacher, taking care to avoid placing your body in the sound path between teacher and student, which can produce inaccurate measurements.

   c. Ask the teacher to begin reading a standard passage; record the teacher voice levels on the form at the various locations using the same procedures outlined in 4b. These measurements provide an estimate of the average signal level during an instructional period.

   d. Determine the SNR of the classroom by subtracting the A-weighted ambient noise level from the teacher voice level at the selected student locations. For example, a student location with a teacher voice level of 60 dBA and an A-weighted ambient noise level of 50 dBA would have a SNR of +10 dB. One with a teacher level of 60 dBA and a noise level of 70 dBA would have a SNR of -10 dB.

   e. Averaging all teacher voice levels and subtracting from the average A-weighted ambient level for the various conditions will calculate an average SNR level.

6. Teacher Voice Levels with Classroom Audio Distribution System (ADS):

    a. Repeat the steps 5a-e above.

    b. Compare results to the condition without the system to determine the benefits of the classroom ADS. The goal is even distribution of the teacher's voice throughout the classroom. For children with special listening needs, an average of at least +15 dB SNR is recommended; this improvement is best attained *not* by increasing the loudness of the classroom ADS beyond that recommended earlier in Sec 4.2 Intensity Levels, but by reducing background noise levels.

Directions for Classroom Reverberation Measurements (Section 3 of the Worksheet)

Reverberation time (RT60) is the amount of time in seconds that it takes a sound to decay by 60 dB in a room. RT60 can be measured with special instrumentation or estimated based on absorption co-efficients of surface materials in a classroom. Each method is outlined below.

Directions for RT60 Measurements:

Equipment needed: Reverberation instrument or sound level meter with reverberation measurement capability, noise generation source such as a balloon or two boards that can be clapped together. Note: These measurements should be made in empty classrooms for accuracy as well as to avoid exposure of occupants to loud noise.

1. Make separate RT60 measurements at 500 Hz, 1000 Hz and 2000 Hz.

2. These measurements require an impulse sound to be generated that is at least 25 dB louder than the background noise in the room. The impulse sound can be produced by dedicated sound generators, or, more commonly, breaking balloons or slapping boards together.

3. Measurements at each frequency should be made in the four corners and the middle of the room. The five measurements at each frequency should be averaged to obtain the best estimate of the RT60 for that frequency in the room. Record this average on the form for each frequency. These locations can also be indicated on the classroom schematic.

4. An overall RT60 estimate in the classroom for the speech frequencies is obtained by averaging the RT60 estimates obtained for 500 Hz, 1000 Hz and 2000 Hz. Record this as the room average RT60.

Directions for Calculating Estimated RT60 Using the Sabine Formula:

The most common formula for estimating reverberation time is the familiar Sabine equation (RT60=.049 x Volume/ Surface Area x Average Absorption). This equation can be used to make paper and pencil estimates of RT60.

Equipment needed: 20 ft measuring tape or laser tape and calculator.

Formula to estimate classroom reverberation time: RT=.049 x V/A where RT=reverberation time in seconds, V=volume room, and A=total absorption of the room surfaces in Sabins.

1. All of the reverberation estimates can be conducted in an unoccupied classroom. Because a formula is used, no improvement in accuracy is obtained with students and teacher present.

2. Calculate the volume of the classroom by measuring the length, width, and height of the classroom in feet and multiplying them together (volume=length of room x width of room x height of room).

3. Record the resulting room volume in cubic feet on the classroom documentation form.

4. Multiply the volume of the room by the constant .049 to obtain the numerator for the RT=.049 V/A equation. Record the results on the form.

5. To obtain the denominator of the equation, the area of the walls, floor, and ceiling of the room must first be calculated in square feet. If the walls, ceiling, or floor are irregularly shaped, each section must be measured separately. The area of the floor and ceiling is determined by multiplying the length of the floor or ceiling times its width. The area of the walls can be obtained by multiplying the length of each wall by its height. Enter the values for the area of each on the classroom documentation form.

6. The absorption coefficient (Abs. Coef.) is a measure of the sound reflectiveness of different construction materials. The coefficient, expressed in Sabins, must be determined for the material composing the walls, ceiling, and floor. Average absorption coefficients are given in the table below for the most common construction materials. If a different construction material is encountered and you use another absorption coefficient table, average the coefficients given in the other table for 500, 1000, and 2000 Hz for the purpose of these calculations. Enter the average absorption coefficient in the appropriate place on the documentation form.

7. Multiply the area of each floor, ceiling, and wall times the absorptive coefficient of the material composing the surface. Add up all of the resultants of the multiplications to obtain the A (total absorption of the room in Sabins) in the RT=.049 V/A formula for the room and record it on the form.

8. Take the numerator from Step 3 (.049 x V) and the denominator from Step 6 (A=total absorption in Sabins for the room) and divide them in order to determine the estimated reverberation time of the room in seconds (RT=.049 V/A). Enter the estimate on the documentation form. It Compare the results to the ANSI/ASA S12.60-2009/2010 standards for the type of room (permanent or portable).

Sound Absorption Co-Efficients for Common Classroom Materials[a]

Material	Ave Absorp Coefficient	Material	Ave Absorp Coefficient	Material	Ave Absorp Coefficient
WALLS		**FLOORS**		**CEILINGS**	
Brick	0.04	Wood parquet on concrete	0.06	Plaster, gypsum, or lime on lath	0.05
Painted concrete	0.07	Linoleum	0.03	Acoustical tiles (5/8”)-suspended	0.68
Window glass	0.12	Carpet on concrete	0.37	Acoustical tiles (1/2”)-suspended	0.66
Plaster on concrete	0.06	Carpet on foam padding	0.63	Acoustical tiles (1/2”)-not suspended	0.67
Plywood	0.12			High absorptive panels-suspended	0.91
Concrete block	0.33				

a Adapted from Berg, F. (1993) by J Smaldino and C. Crandell (1995). In Sound-field FM Amplification, Crandell, Smaldino, & Flexer (Eds.) p. 78. Singular Publishing Group, Inc. Reprinted by permission. See RT60 Web sites for a more comprehensive list of materials.

Directions to Determine Approximate Critical Distance (Section 4 of Worksheet)

Using the table below, match the volume and estimated reverberation time of the room being analyzed. The resulting value is the critical distance. Up to and including this distance from the talker, reflections from the sound reverberating in the room will enhance the speech signal; beyond this distance the speech signal will be degraded by the later reflections of the sound reverberations. For example for a room of 10,000 cubic feet and a reverberation time of .4 seconds, the critical distance is 10 feet. It is important that students with special listening requirements are not positioned any further than 10 feet from the talker in this situation to receive the most intelligible signal from the talker.

Estimated Critical Distance Table[b]

Room Volume (Cubic Ft)	Reverberation Time (seconds)							
	.3	.4	.5	.6	.7	.8	.9	1.0
2000	5.2	4.5	4.0	3.7	3.4	3.2	3.0	2.8
4000	7.3	6.3	5.7	5.2	4.8	4.5	4.2	4.0
6000	8.9	7.7	6.9	6.3	5.9	5.5	5.2	4.9
8000	10.3	8.9	8.0	7.3	6.8	6.3	6.0	5.7
10,000	11.5	10.0	8.9	8.2	7.6	7.1	6.7	6.3
12,000	12.6	11.0	9.8	8.9	8.3	7.7	7.3	6.9
14,000	13.7	11.8	10.6	9.7	8.9	8.4	7.9	7.5
16,000	14.6	12.6	11.3	10.3	9.6	8.9	8.4	8.0
18,000	15.5	13.4	12.0	11.0	10.1	9.5	8.9	8.5
20,000	16.3	14.1	12.6	11.5	10.7	10.0	9.4	8.9
	Critical Distance (feet)							

[b] © Arthur Boothroyd, used with permission

Classroom Acoustical Screening Survey Worksheet[1]

Date ______________________ Audiologist/Surveyor ______________________________________

School ______________________ Room __________ Teacher ______________________________

Student Name (if applicable) ____ Grade ________

This worksheet is intended to be used to screen for acoustical problems in classrooms. When noise and/or reverberation levels are suspected of exceeding those recommended by ANSI/ASA S12.60-2009/2010, the screening survey data is an indicator for further assessment. This assessment may include a referral to an acoustical specialist who can perform a comprehensive acoustical analysis and suggest solutions.

1. Observation Information

A classroom observation is a preparatory step for making classroom acoustical measurements. The observation provides information about acoustical parameters of the classroom as well as the style of instruction, seating arrangement and communication access.

Background Noise

Listen in the classroom and check for the following; a "yes" is an indicator of potentially excessive levels of noise.

Classroom Features	Yes	No
Heating and ventilation system is audible		
Mechanical equipment must be turned off during important lessons		
Noise from playground is audible		
Noise from automobile traffic is audible		
Noise from air traffic is audible		
Noise from incidental sound sources (e.g., electronic equipment, classroom animals, music)		
With heating and ventilation system turned off, sounds from other classrooms, learning spaces or hallway are audible		

1 *Source:* Adapted from Acoustic measurements in classrooms by J. Smaldino, C. Crandell, & B. Kreisman, 2005. In *Sound Field Amplification,* Crandell, Smaldino, & Flexer (Eds.) p. 131. Thomson Delmar Learning.

Reverberation

Overall reverberation is determined by the volume of the room and the absorptive characteristics of the materials making up the classroom walls, floors and ceilings. Check the classroom for the following surfaces; a "yes" is an indicator of potential long reverberation times.

Classroom Features	Yes	No
A hard surface, flat ceiling without acoustical ceiling tiles		
Ceiling height is over 11 feet		
Acoustical ceiling tiles have been painted		
Walls are constructed of sound reflective materials (e.g., plasterboard, concrete, wood paneling)		
Floors are constructed of sound reflective materials (e.g. concrete, tiles, wood)		

Current Technology in the Classroom (if used)

☐ Personal FM [Number of students ________] Type ____________________

☐ Classroom ADS: Whole Classroom Type ____________________

☐ Classroom ADS: Targeted Area Type ____________________

Teacher to Listener Distance

Nearest ________ Ft Farthest ________ Ft

Classroom Style

☐ Traditional ☐ Open ☐ Portable/Relocatable

Primary Instruction Style

☐ Lecture ☐ Large Group ☐ Small Group ☐ Individual Other ____________________

Seating Arrangement

☐ Clusters ☐ Rows ☐ U-shape or Circle Other ____________________

2. Noise Measurements

Classroom Schematic Diagram

see attached

Sound Level Meter

Make/Model# ________________________________

Method Used

☐ One Hour Average ☐ Short-Term: ________ second average; # of time samples ________

Ambient Noise Levels (dBA, dBC) Unoccupied and Occupied Classroom

Teacher Voice Levels (dBA): Occupied Classroom

Condition (circle number for condition):		**1** = unoccupied, HVAC off; **2** = unoccupied, HVAC on; **3** = occupied, HVAC off **4** = occupied, HVAC on								Without Classroom ADS ☐ **Hon** ☐ **Hoff**		With Classroom ADS ☐ **Hon** ☐ **Hoff**	
		1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4		Level	SNR	Level	SNR
Weighting:		A	C	A	C	A	C	A	C	A	A	A	A
Measurement Locations	A*												
	B												
	C												
	D												
	E												
	F												
Ave dB Level:													

* Target Student

Comments:

3. Reverberation Time

Measured

Sound stimulus used: ______________________________

Frequency		500 Hz	1000 Hz	2000 Hz
Measurement Locations	A			
	B			
	C			
	D			
	Middle			
RT60 Ave Seconds:				

RT60 Classroom Average:

______________ seconds

Estimated

Note: Online RT60 calculation programs may also be used for this calculation
(e.g., www.sengpielaudio.com/calculator-RT60.htm, www.mcsquared.com/homerteng.htm).

Room Volume (V) = ______________________ cubic feet

Area Floor ______________ x ABS. Coef. ______________ = A Floor ______________

Area Ceiling ______________ x ABS. Coef. ______________ = A Ceiling ______________

Area Side Wall 1 ______________ x ABS. Coef. ______________ = A Wall 1 ______________

Area Side Wall 2 ______________ x ABS. Coef. ______________ = A Wall 2 ______________

Area End Wall 1 ______________ x ABS. Coef. ______________ = A End 1 ______________

Area End Wall 2 ______________ x ABS. Coef. ______________ = A End 2 ______________

Total A ______________

Estimated Average RT of Classroom = .049 x ______________ (V) / ______________ (A) = ______________ seconds

Comments:

4. Estimated Critical Distance:

_______________ Ft

Recommended Classroom Acoustical Standards for Core Learning Spaces <10,000 ft^3 volume (ANSI/ASA S12.60-2009, 2010)	
Permanent Classrooms	Ambient Noise Level: 35 dBA/55 dBC; Reverberation Time: .6 seconds*
Relocatable Classrooms	Ambient Noise Level: 41 dBA, [38 dBA by 2013, 35 dBA by 2017] Reverberation Time: .5 seconds

* Note: Core learning spaces in permanent classrooms shall be readily adaptable to allow reduction in reverberation time to .3 seconds to accommodate children with special listening needs. Relocatable classrooms are generally not suitable for any child with special listening requirements due to higher noise levels.

APPENDIX 7.2

Classroom Behavioral Verification/Validation Worksheet for Personal FM and Classroom Audio Distribution System (ADS) Use

Name ______________________ Date of Birth ______________________

Examiner ______________________ Date of Evaluation ______________________

School District ______________________ ADS/ FM systems coupling: ☐ Direct ☐ Indirect

Current Technology in the Classroom (if used)

☐ Personal FM [Number of students __________] Type / SN ______________________

☐ Classroom ADS: Whole Classroom Type / SN ______________________

☐ Classroom ADS: Targeted Area Type / SN ______________________

	Y/N	Background Noise	Y/N	Reverberation
Classroom Acoustics		Heating, ventilation, and air conditioning (HVAC) system is audible		A hard surface, flat ceiling without acoustical ceiling tiles
		Noise from incidental sound sources (e.g., electronic equipment, music)		Ceiling height is over 11 feet
		Noise from playground is audible		Acoustical ceiling tiles have been painted
		Noise from automobile traffic is audible		Walls are constructed of sound reflective materials
		Noise from air traffic is audible		Floors are constructed of sound reflective materials
		HVAC off, are sounds audible from hallway/ classrooms		More than 50% of a single wall consists of windows
Informal Behavioral check	☐ Listening check for HA/CI/BC alone ☐ Listening check for classroom ADS @ _____ dB Comments:		☐ Informal behavioral check HA/CI/BC alone ☐ Informal behavioral check HA/CI/BC+FM	

	Right Ear: HA/CI/BC	Left Ear: HA/CI/BC
Equipment Verification	Manufacturer:	Manufacturer:
	Model:	Model:
	Serial No:	Serial No:
	Use Settings:	Use Settings:
	FM receiver model:	FM receiver model:
	Serial No:	Serial No:
	Audio shoe:	Audio shoe:
	FM Program:	FM Program:

Formal Behavioral Evaluation: Speech Perception Testing		
	Without FM/ADS: % correct score __________ List(s): Presentation level:	**With FM/ADS:** % correct score __________ List(s): Presentation level:

Classroom Validation	
	Listening Inventory for Education (LIFE) Questionnaire: Completed by ______________________ Without Classroom ADS: ______________ (date) With Classroom ADS: ______________ (date)

Key: ADS=Audio Distribution System; SN=Serial Number; HA=Hearing Aid; CI=Cochlear Implant; BC=Bone-Conduction Hearing Device