CHAPTER TEN

New Developments in FM Systems for Infants and Children

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It is easy to forget how far FM system technology has progressed in a relatively short time. Only body-worn FM receiver styles were available up to the early 1990's and audiologists had few decisions to make when it came to fitting FMs or auditory trainer systems. Initially a child who used an FM system or auditory trainer removed their personal hearing instrument and donned a body-worn FM receiver box with button-type transducers and chest-level environmental microphones. This was required to allow an FM transmission between the teacher's microphone and the child's receiver. These self-contained FM systems had linear processing with minimal fine-tuning or adjustments available. Fixed FM transmission frequencies and fixed FM gain levels allowed little flexibility in the fittings. Because of the size of early FM systems, they were rarely used outside of classroom settings. FM use outside of the child's classroom was awkward, inconvenient and rarely implemented. Even if parents or teachers were motivated to use remote microphones and FM transmission to improve listening in poor acoustic environments outside of the classroom, the size of the receiver and the placement of the environmental microphone on the child's chest were simply impractical (Moeller , Donaghy, Beauchaine, Lewis and Stelmachowicz 1996).

Miniaturization of the FM receiver has made it possible to partially integrate the receiver into personal hearing instruments, allowing FM systems to be used in many different listening and learning environments outside of a traditional classroom. FM use should be considered in any situation at home or outside of the traditional classroom where background noise or distance from the primary talker would make listening and learning difficult. Advances in digital signal processing have moved from the exclusive realm of hearing instrument processing to offer expanded functions in both FM transmitters and receivers beyond a single fixed transmission channel and FM gain level. The many processing and configuration options that are available require audiologists to make a greater number of decisions when configuring an amplification system for a child or student. Clinicians must balance the use of these FM features with the changing needs of children from infancy to young adulthood.

As FM receivers have gotten smaller and are becoming more directly integrated into personal hearing instruments, the educational audiologist's and the dispensing audiologist's roles have become more collaborative. All current FM receivers access personal hearing instruments in some way, with the exception of Ear-Level FM-Only devices such as the Phonak Edulink® and iSense® and sound field systems. Because most FM receiver function is dependent upon the settings and function of a child's personal hearing instruments, collaboration and communication between dispensing and educational audiologists is critical to ensure that a child's FM system functions well. Any time the child's hearing instrument model changes, the appropriate DAI (direct auditory input) connection will be needed so the FM receiver can connect to the hearing instrument properly. This requires the dispensing audiologist to inform the educational audiologist that the child's hearing instruments are being changed so that appropriate DAI connections can be obtained. Many digital hearing instruments have a separate FM program that must be activated for it to receive FM inputs. The educational audiologist needs to inform the dispensing/clinic-based

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audiologist when a child will be using an FM system and what type of receiver is available so that the dispensing audiologist can ensure that the hearing instrument is properly programmed to receive the FM input. A functioning FM system depends on the child having hearing instruments that are programmed for appropriate audibility and FM access. Decisions such as how to set the hearing instrument's start-up program and who will verify the FM function may vary from school district to school district. The key is setting up an efficient means of communication that includes critical information about FM systems, hearing instruments and test results that can be shared between audiologists. Good school and clinic collaborations make effective implementation possible.

The goal of this chapter is two-fold. First, to review current FM technology options and their functions. Second, to discuss the decision-making process when choosing the components of an FM system for different age groups.

Current FM Device Options

The Dynamic FM platform currently available in Phonak's FM devices provides a number of significant advances in transmitter and receiver functions. To access all of the Dynamic platform's advanced features, a specific transmitter and receiver combination is required. A sub-audio digital code coming from the transmitter must be read by the receiver and the receiver must also be able to send a digital code back to the transmitter. Transmitters and receivers can function when non-Dynamic FM transmitters are used with dynamic receivers and vice-versa, but most of the advanced features are not available. In all cases, verification of the specific transmitter and receiver combination is recommended to confirm that all components are functioning as expected for a child. A recent review of electroacoustic verification measures with a variety of FM transmitters, receivers and hearing instrument models by Symington and deConde Johnson (2010), indicated significant variation from FM transparency when transmitter and receiver models were mixed between FM manufacturers and models, confirming the need for electroacoustic verification of the entire amplification system.

The new Phonak FM platform available in Inspiro® receivers removes the need for programming adjustments to the receiver related to impedance variations that are encountered with the various DAI input processing features of different hearing instrument models and manufacturers. This "AutoConnect" feature also eliminates the need to program the FM receiver differently for hearing instruments that have a designated program for DAI than for those that do not have a designated FM program, commonly referred to as "DPAI-yes" or "DPAI0-no". Results from Symington and deConde Johnson (2010) indicated that the AutoConnect feature in Inspiro universal receivers (MLxi®) resulted in more verification results at "out-of-the-box" default settings that achieved electroacoustic transparency regardless of the hearing instrument model evaluated, although electroacoustic verification was still recommended as transparency was not achieved in every case. Further information about electroacoustic verification procedures can be found in Supplement A of the American Academy of Audiology's Hearing Assistance Technology (HAT) Guidelines (2008).

The most obvious advance with Dynamic FM that is experienced by the FM user is Adaptive FM Advantage (AFMA) in Phonak transmitters and Dynamic Platform ("i") receivers. Rather than a fixed FM-gain level, Adaptive FM Advantage automatically increases the FM gain level in the receiver as background noise levels increase above 57 dB SPL at the transmitter microphone. A measurement of ambient noise levels is performed in the speech pauses of the teacher or primary talker wearing the FM transmitter. Increases in background noise will signal the FM receiver to increase gain via the sub-audio digital code being transmitted between the transmitter and receiver. The receiver's FM gain level will continue to increase as background noise levels increase from 57 to 73 dB SPL, with the FM gain capable of increasing as much as 24 dB in relation to the hearing instrument microphone level in high background noise situations. The actual maximum FM gain level available for each user will be dependent upon the maximum output settings and the overall dynamic range of the hearing instrument. When background noise levels drop below 57 dB SPL, the FM receiver gain also returns to the original programmed starting level. The receiver's default FM gain level is programmed to provide a +10 dB FM advantage over the hearing instrument's microphone in quiet environments, but this starting FM gain level can be adjusted as needed for an individual child by using an Inspiro transmitter's extended programming functions or via a programming interface with Phonak's FM programming software (FM Successware®). The overall effect of increasing FM gain is an increase in compression on signals coming into the hearing instrument microphone, which may effectively decrease audibility of

other talkers and signals in the listening environment. Few studies are available that evaluate the benefit of this newest FM processing platform or AFMA specifically. Two current small clinical studies, one evaluating benefit of adaptive FM with cochlear implants and one with digital hearing instruments (Wolfe, Schafer, Heldner, Mulder, Ward and Vincent 2009 and Thibodeau 2010), suggested that hearing-impaired subjects that used FM systems had better word recognition scores with Adaptive FM than with conventional fixed FM advantage when background noise levels exceeded 60 dB SPL. Users preferred the Adaptive FM Advantage systems when judging the audibility of the primary talker and overall sound quality. The adaptive FM gain feature is found in all current Phonak FM receivers, including all dedicated receiver models, the universal MLxi receiver, the MyLink+® inductive loop receiver and the Dynamic SoundField® receiver/loudspeaker system.

Transmitter Features

Transmitter and receiver monitoring, datalogging and multi-talker network features function with the Dynamic FM platform only when an Inspiro model transmitter is used in combination with dynamic platform ("i") receivers. When using other Phonak transmitter models that function on the Dynamic FM platform (SmartLink+®, ZoomLink+®, EasyLink+®, and DynaMic®), only the adaptive FM gain feature is available. A team-teaching feature is available in the most current Oticon Amigo® FM systems, although, as stated previously, when transmitters and receivers are mixed and matched across models and manufactures, some functions are lost.

Phonak Inspiro transmitters can perform and record monitoring activities to confirm a connection with the child's Inspiro receiver. When monitoring is performed, the transmitter displays information about the hearing instrument's battery status, the integrity of the receiver connection through the audio shoe, the FM channel being used and the receiver FM gain settings. Results from monitoring tests are recorded and available for review. Oticon Amigo systems have an LED monitoring function on the receiver that can be programmed to light up and blink to confirm that the hearing instrument battery is working, the receiver is on and is receiving an FM signal. Monitoring is on-going with a visual indicator display, but it is not recorded for later review. Both Phonak Inspiro and Oticon Amigo transmitters can measure and monitor background noise levels and give an indication if the microphone placement needs adjustment to optimize the speech input level to the microphone.

Datalogging has been a feature available for several years in digital hearing instruments. Datalogging has now been implemented in Phonak Inspiro transmitters and allows the audiologist to review how and when the transmitter is being used, overall ambient noise levels present when the microphone is active, as well as providing a record of monitoring activities. Data from the Inspiro transmitter can be downloaded to a computer using Phonak's FM Successware. Datalogged information may be viewed by the week or by the month. It provides the managing audiologist with critical information that would be difficult to obtain without spending all day everyday in the child's classroom or home environment. This includes overall transmitter use time per day as well as the results of monitoring tests performed with the Inspiro. If problems are identified during monitoring checks, the managing audiologist can determine what type of problem was present and how long the problem occurred. Ambient noise levels at the transmitter are recorded in 15 minute intervals and are divided into two noise categories: low ambient noise, defined as less than 65 dB SPL and high ambient noise with levels greater than 65 dB SPL. Information about ambient noise level provides a strong indication of whether Adaptive FM Advantage was activated while the FM system was in use.

The Phonak Inspiro transmitter can be programmed to access a multi-talker network. The multi-talker network allows multiple transmitters to work together without the addition of interference or noise into the signal that is transmitted to the receiver(s) in the classroom. A network of multiple Inspiros or a combination of Inspiro and DynaMic transmitters can be activated for classrooms using a team-teaching model or when teachers use a secondary microphone to enhance student participation. Using the Dynamic FM platform, all transmitters in the network communicate with each other in a 2.4 GHz range rather than creating potential interference with FM receivers operating in the 216-217 MHz range. When one person is talking, all other transmitters in the network go to stand-by, eliminating the potential of additional noise in the transmitted signal. When the network is active, one Inspiro transmitter is designated as the primary transmitter; when the person using the primary transmitter starts to talk, that input will override any other talkers and preserve the primary teacher's voice. A team-teaching option also is available

Current FM Developments	Feature Summary
Adaptive FM Advantage (AFMA)	Increased FM gain level with increased background noise
Datalogging	Tracking of monitoring activities Tracking of transmitter & microphone use-time per day Tracking of ambient noise levels
Multi-talker Networks / Team-Teaching	Multiple transmitters functioning on one frequency without interference
Monitoring Functions	Battery status Audio Shoe connection Channel synchronization Optimum microphone placement
Microphone Directionality	Manually switchable or programmable directionality of lavaliere-style microphones

Table 1. Summary of Current FM Features

in Oticon's Amigo T21® transmitters. It allows multiple T21 receivers to communicate with each other on a frequency in the 216-217 MHz range that is not adjacent to the receiver frequency, although some risk of interference exists. All Amigo transmitters are active at the same time, so no primary talker is designated.

FM microphone directionality is a switchable option available with lavalier-style microphones, such as Phonak's SmartLink+ and ZoomLink+ or Oticon's Amigo T10®. The ability to choose between an omnidirectional and wide or narrow-width directional setting can expand the flexibility of transmitter use outside of typical classroom lecture settings, allowing transmitters to be used as small conference-type microphones or as user-controlled "pointer" microphones in noisy social settings.

Receiver Features

All current FM receivers are frequency-synthesized, making them simple to switch between transmitters operating on different channels. Ear-level FM receivers are available in one of two styles: universal and dedicated. Universal ear-level receivers are switchable between any and all hearing instrument manufactures and models that have direct audio input (DAI) capability and an appropriate DAI shoe, making them easy to adapt if a child's hearing instrument is changed. Universal receivers can also be used on CI processors that have the appropriate auxiliary input connection. Dedicated FM receivers are integrated into the battery compartment of a hearing instrument or CI processor. They connect to a specific hearing-instrument or CI model or case design and have a smaller overall size than a universal receiver plus DAI shoe combination. With a dedicated receiver, the DAI shoe is eliminated and the receiver cannot fall off or be easily removed, reducing the likelihood of its being pulled off or lost. If a child's hearing instrument model is changed, a dedicated FM receiver cannot be adapted and must be replaced.

The choice between universal and dedicated receivers is typically based on issues related to overall size of the amplification system, the need for loss prevention, adaptability and transferability of the receiver across different hearing instrument models. Most school districts own a stock of universal FM receivers that can be used interchangeably between students. Families may choose dedicated FM receivers more frequently because of the smaller overall size and better integration into the hearing instrument's case.

Current ear-level FM receivers require a connection to a behind-the-ear hearing instrument in order to provide the FM signal to the child or student. Because both universal and dedicated receivers access the hearing instrument in a similar way, it is assumed that the hearing instrument's gain and output has been set or programmed to provide optimum audibility for the child. This is critical as the gain and output characteristics of the FM signal are primarily determined by the hearing instrument. If the hearing instrument is not providing

optimum audibility for a child's hearing loss, then neither will the FM system, despite all the advanced features available. Thus, hearing instrument verification using probe-microphone measures must be confirmed before the FM receiver is connected. Documentation of amplified audibility of the hearing instrument alone and with the FM system activated should be shared between clinical and educational audiologists to ensure that the FM system is set and functioning properly. Any adjustments to a child's personal hearing instrument programming should be verified and coordinated between clinical and educational audiologists when the child's hearing instruments are used as part of the amplification system in school.

While the main focus of this chapter is on amplification systems that utilize ear-level FM receivers combined with hearing instruments or CIs, many advanced FM features are available in other types of receivers, including ear-level FM-only receivers such as the Phonak iSense, neckloop or induction receivers such as the Phonak MyLink+ and Oticon Arc® and now in the Phonak's Dynamic SoundField system. The power of the newest FM technology platforms is that various types of receiver interfaces can be combined within the same classroom with the teacher needing only one transmitter to transmit to all the different types of receivers.

The FM Implementation Process

Choosing the appropriate FM transmitter and receiver combination does not exist in isolation. The combined hearing instrument and FM system need to be viewed as a complete amplification system. Children with hearing loss are assumed to be potential candidates for use of an FM system, but that is just a starting point. A structured decision protocol is available to assist audiologists when putting together an FM transmitter/receiver combination that is best for the child, the family, the school and for the child's future academic placements. The AAA HAT Guidelines (2008) provide a helpful structure to work through a 5-Step HAT Intervention Process.

- Step 1 determines the child's potential candidacy, of which hearing loss is a primary qualification. Other potential candidates include normal-hearing children with auditory processing difficulties, attention deficits and learning disorders.
- Step 2 of the process addresses implementation considerations that must be considered before introducing the use of any type of hearing assistance technology such as an FM system. A child may be a potential candidate for an FM system but acoustical environment, social-emotional factors, financial considerations and acceptance of the device by the child, family and teacher(s) influence the final decision about whether or not to implement the use of an FM system.
- Device selection considerations are the 3rd step in the implementation process and one that is the primary focus of this chapter. With so many choices available, it is important to consider the child's listening and learning environments at home and/or school and their technology and acoustic needs when making selection decisions.
- Step 4 addresses the fitting and verification of the FM system that is chosen for the child to use.
- The 5th Step of the process addresses orientation, training and monitoring of the system selected.

Verification and on-going monitoring are critical steps, though not addressed directly here. No matter how technologically superior FM systems are, they will be completely ineffective for the child if the hearing instrument has not been programmed to accept an FM input, the hearing instrument is not providing appropriate audibility, or the direct audio input and FM receiver are not making a proper connection. If no one in the child's home or classroom understands how the system works and no one is monitoring its function there is no assurance that the system will work appropriately after it is fit. The reader is encouraged to review the AAA HAT Guidelines (2008) and use the supplemental Implementation Worksheets available to assist in reviewing and documenting the complete implementation process.

Before a particular system is chosen for a child, some general considerations regarding FM and hearing instrument connections must be considered. No matter what specific features are selected, the method of accessing the FM input has implications for the child using the system. For example, with current Phonak hearing instrument models FM input can be accessed either through an activated EasyFM program, a Manual FM+M program that the child, teacher or parent accesses, or a default start-up program set to FM+M. In current Phonak instruments, an FM+M start-up program means that the hearing instrument programming will always be set to the Calm (quiet environment) processing even when no FM input is present. If the child encounters varying degrees of noise, no further noise reduction processing will be employed unless the child manually changes the active program in the hearing instrument. An EasyFM program would allow other

automatic hearing instrument processing features to remain active when the FM transmitter is not being used. However, if the child has EasyFM programming in a school building with more than one transmitter in use, the EasyFM may be activated by various transmitters when the child moves from class to class, even if FM transmission is unwanted. Keeping the FM input restricted to a manually accessible program means that someone must change the program to the designated FM program whenever the FM system is being used and then switch it back to its default setting when it is not. If the child is unable to recognize the program signal or report that it has been changed, a teacher or parent must monitor and check the hearing instrument settings.

Both the dispensing and educational audiologist should have input into deciding the best FM access setting for a particular child. The overall balance of the FM input with other inputs into the hearing instrument microphone may also require a team approach with the dispensing audiologist, educational audiologist, teacher and child working together for an optimum fitting. Other general considerations include choosing a hearing instrument and FM system combination that allows for battery changes and turning the hearing instrument off and on without removing the DAI boot and FM receiver, thereby minimizing wear and tear on the connections. Overall size of the entire amplification system with the FM receiver attached can be critical for very small ears and small heads.

Other important considerations that must be addressed when considering what transmitter and receiver combination to choose are how and where the system will be used.

- Is this a system that will be used at home only, at home and school or school alone? Parents who use an FM system at home with an infant or young child may need monitoring functions to allow them to easily check the FM connection and the hearing instrument battery status. A dedicated FM receiver will reduce the overall size and bulk of the ear-level device and provide a secure FM combination that is not easily removed or lost. For an older child who must transport a transmitter from class to class, the best option may be the ease and adaptability available from a lavalier-style transmitter microphone such as an EasyLink+, ZoomLink+ or Amigo T10. An older student who is concerned about the visibility of an ear-level FM receiver may agree to continued FM use if an iCom® with universal receiver, MyLink+, or Arc connection can be concealed beneath their clothing.

Urban schools that have higher numbers of children with hearing loss are more likely to own and distribute a complete amplification system that includes hearing instrument(s), FM transmitter and receiver(s) to the child for use during the school day. This is an efficient means of assuring that children have access to functioning equipment regardless of the status of their personal hearing instruments. FM transmitters and receivers must be completely interchangeable so that they can be switched out easily if a problem is identified. In this situation, the educational audiologist determines the most flexible system that can be used district-wide and builds a stock of hearing instruments, transmitters and receivers that can be quickly available to the students who need them. In this setting, universal receivers are needed. With a complete stock of hearing instruments, having the appropriate compatible DAI shoes can also be controlled.

Smaller school districts have a limited number of children needing hearing instruments and FM systems for education. In this setting, students are more likely to use their personal hearing instruments with an FM system that is owned by the school. The FM transmitter and receiver often follow the same child through several grades and sometimes through more than one set of hearing instruments. The educational audiologist or consulting audiologist must consider the pros and cons of fitting a dedicated versus universal receiver, even if the system is likely only to be worn by one child.

- How is the FM transmitter going to be used? Team-teaching situations previously required a complicated combination of "daisy-chained" FM transmitters that all transmitted on different frequencies with each other in a chain. This had potential for interference and a poor quality signal to the child wearing the receiver. With new multi-talker or team-teaching networks available, this is no longer a problem. The microphones that are chosen must be able to work together on the team-teaching frequency or the multi-talker network and this restricts transmitter choices to those that can communicate with each other. With Phonak products this requires two or more Inspiro transmitters or an Inspiro with one or more DynaMics, which can be programmed to work on the network. Current Oticon Amigo systems require T21 transmitters with all transmitters having the TT (team teaching) option enabled.
- Will the teacher be transmitting only to an ear-level FM receiver worn by an individual child or will the transmitter also be needed for use with a classroom

sound field system that is in place for the entire room? The educational audiologist may need to compromise some of the transmitter features that are available in order to prevent the classroom teacher from having to wear multiple transmitters and microphones. This especially true when personal FM and sound field systems are mixed and matched.

Technology Priorities by Age Range

FM applications can be divided into four basic age categories, based on where and how the FM system will be used. Overall FM candidacy considerations and individual characteristics of the child and the listening and learning environment will drive the decision process. The main categories to consider:

- children under 2 years of age (typically not in a school-based setting)
- preschool age (3-5 years)
- primary school grades
- secondary school and beyond

Under 2 Years

Children under 2 years of age are typically not in a structured educational setting. Even so, high noise environments such as traveling in the car, playing in play groups or attending museums or zoos may still impact the child's ability to hear and understand their parent or primary caretaker's voice. As children start to crawl and walk, variable distance from the primary talker will further impact audibility. The judicious use of FM technology coupled to current hearing instrument technology will increase language input opportunities in these difficult listening environments. When a child is placed in a car seat or stroller facing away from a parent, and background noise levels are high enough to significantly degrade the speech input to the child's hearing instrument, the use of an FM system can keep a clear communication channel available. Home use of FM systems is not recommended full-time, but for those listening environments in which communication would be difficult or impossible without a remote microphone. Parents and primary caretakers need information counseling and training to be able to evaluate their child's communication environments and determine when FM system use would be beneficial. The family's ability to use and manage the additional technology will impact FM system benefit in this age category. Financial/funding considerations also impact the ability to make FM technology available for all infants and young children.

The main priorities for selecting FM system features in this age category are making monitoring functions available and having a small system that will fit the child's ears and head. At this young age, children are not able to provide feedback to the caregiver as to whether or not the FM system is working properly. Monitoring functions that show if the FM system is con-

Age Range	Top Priorities	Best FM Features
Infants / Young Children under 2 years	• Monitoring FM Function • Loss Prevention • Size	• Monitor Features & Datalogging • Dedicated FM Receiver
Preschool ages 2-5 years	• Monitoring FM Function • Loss Prevention	• Monitor Features & Datalogging • Dedicated FM Receiver
Primary School Age	• Adaptability with other devices • Datalogging • Monitoring FM Function	• Team-Teaching / Multi-talker Networks • Monitor Features & Datalogging
Secondary School Ages and Beyond	• Size and Portability • Adaptability with other devices	• Lavaliere-style transmitter • iCom™ with universal receiver or Neckloop receiver

Table 2. FM System Priorities by Age Range

nected and the strength of the hearing instrument battery gives caretakers visual assurance that the system is working properly. The most complete monitoring options are available in the Phonak Inspiro transmitter/receiver systems which shows connection and battery information and also records the information into datalogging memory. A dedicated or semi-integrated FM receiver will reduce the overall size of the amplification system on the infant or young child's ears, which improves hearing instrument retention and the cosmetics of the fitting. With a dedicated FM receiver integrated into the hearing instrument's battery door, there is a reduced risk of having the receiver accidentally removed or lost. If the FM system is used both at home and in a daycare setting, the entire system of transmitter, receiver and hearing instrument must be simple to use with few manual steps needed to ensure that the FM signal is being accessed. Having a hearing instrument with an AutoFM or EasyFM program that automatically switches to the FM program when an FM signal is detected can reduce confusion about whether or not the child is receiving the FM signal.

Preschool

Children who are 3-5 years old may be in more structured educational/classroom environments for part of the day, but continue to be good candidates for home use of an FM system. The FM system that is chosen needs to easily switch between educational and home use. A dedicated FM receiver will reduce the overall size of the system and prevent accidental removal or loss of the receiver. When a dedicated FM receiver is used at home with a child's personal hearing instruments, parents may prefer that the hearing instrument/FM system be used for preschool activities, as well. In this case, the FM transmitters used at school and home should function on the same platform and ideally would be the same transmitter model. This would prevent any changes in performance as the child transitions between school and home. The use of EasyFM or AutoFM can improve the ease of use in the preschool population, as it eliminates the need for manual switching of the hearing instrument(s) when the FM system is activated by parents and teachers. FM ownership and issues related to responsibility for maintenance and repair need to be agreed upon in advance between school and parents.

As with infants and younger children, the need for monitoring functions is critical in the preschool age range, as children still may not be able to give a teacher or parent reliable feedback about FM system performance. A Phonak Inspiro system will allow monitoring and logging of monitoring results to track problems. Clinical and/or educational audiologists will have access to a variety of datalogged information in addition to monitoring functions. Important information about ambient noise levels in the classroom and transmitter use times can be tracked over days, weeks and months. Educational audiologists will likely be responsible for tracking FM systems used in the classroom and clinical audiologists responsible for information from FM systems used at home. However, both need access to a computer connection and current Phonak FM Successware software to download and review information stored in the Inspiro transmitters.

The preschool classroom environment needs to be evaluated carefully to determine how the FM transmitter(s) will be used. In a preschool program with multiple children wearing amplification systems, the need for a multi-talker network will depend on the teaching structure in the classroom. If instruction is designed around learning stations with multiple teachers teaching different groups simultaneously, a multi-talker network would be ineffective. The Inspiro multi-talker network is designed so that only one teacher would be heard at a time and the designated primary teacher would likely be the only talker heard on the network in this situation. Other team-teaching systems such as the Oticon Amigo system would transmit the voices of all the teachers to all receivers simultaneously. Multiple simultaneous instruction stations would indicate the need for each transmitter to function on non-overlapping channels, with children manually synchronized to each teacher's transmitter as they move from station to station. During instruction times with the entire class together, a multi-talker network could be activated to allow team instruction or to allow children to take turns leading or speaking to the class. In preschool programs with only one child using an amplification system, there may be only one transmitter which must be passed from teacher to teacher, which will require coordination if there are multiple teachers.

Primary School

FM applications in school may take a higher priority when a child reaches school age, as more of the child's day is spent in the classroom environment. However, home use of FM does not stop when a child reaches school age and, in fact, applications for outside-of-school

activities may increase. If a child is involved in extra-curricular activities such as sports and clubs, an FM system will continue to provide a listening advantage in poor acoustic environments.

Two extremely different educational situations exist when it comes to school applications of FM technologies in large urban school districts as compared to small rural schools. In large special education districts, there is a higher likelihood that dedicated or contracted educational audiology support is available. Due to the higher numbers of hearing-impaired students present in this type of setting, the district may choose to provide an entire amplification system to all students with hearing impairment, including hearing instrument, FM receiver and FM transmitter with appropriate connections for one or both ears. The educational audiologist assumes control for selecting and verifying the systems for all the children in the district who require them. This is to ensure that amplification and an FM system are available at all times, even if the child does not have appropriate or functional hearing instruments when they come to school. Keeping a stock of hearing instruments, universal FM receivers and FM transmitters allows the educational audiologist to provide a compatible system that is easily and quickly exchanged when repairs or adjustments are needed for the child. The amplification system is seen as a modular system with each part compatible with all the others and easily switched in and out as needed. To provide a complete amplification system, the educational audiologist will typically restrict the number of options available in terms of hearing instrument models and types and styles of FM receivers and transmitters in order to provide the most flexibility across all students served. The educational audiologist is also responsible for over-seeing in-service training on FM use and monitoring with classroom teachers.

In small rural school districts with no dedicated educational audiology services available, the child's clinical or dispensing audiologist will often be required to fill the role of educational audiology consultant. The clinical and/or dispensing audiologist providing services to the child must take responsibility for determining the appropriate style and features of both the child's personal hearing instruments and the FM system used at school. Rural school districts may only have 1 or 2 students in the entire district who need an FM system. It may not be feasible to provide an entire amplification system, so the child's personal hearing instruments must be available and functioning for the FM system to provide appropriate benefit. The school often purchases an FM system for a child as needed and the system stays with that child over several grades even if the child's personal hearing instrument changes. When the child's personal hearing instruments are used with a school-owned FM system, responsibilities for hearing instrument repairs related to FM system use in school should be agreed upon in advance by parents and school administrators. The clinical audiologist must also coordinate with the rural school administration or special education/deaf education consultant to determine how FM training for the child's teachers will be provided and who will provide on-going monitoring and trouble-shooting of the system.

In-school FM system applications in the primary grades have technology and feature priorities that are similar to the decisions made for pre-school ages. This is especially true for lower primary grades, where monitoring features may be more necessary if children are not able to give reliable feedback about how the FM system is working. The use of a multi-talker network or team teaching microphones can be helpful if co-teachers are working together with the entire class or students. If the primary classroom implements level-based instruction, this may entail simultaneous instruction happening in different groups or levels. As in the preschool situation described above, a multi-talker network would be ineffective in this type of teaching environment as there is not a primary teacher for the entire group. If there is one child using an FM system in the classroom, multiple transmitters will need to manually synchronize the FM receiver channel or one transmitter will need to be transferred from teacher to teacher in the various learning stations or levels.

Any type of personal FM system used in school should be compatible with other listening and learning technologies present in the classroom, including sound field amplification systems (FM and infrared), interactive whiteboards and computers. Auxiliary inputs to the FM transmitter will allow direct transmission from a digital whiteboard or computer to the child with a personal FM. Personal FM and sound field FM compatibility is more variable. Some sound field systems may have impedance mismatches with personal FM transmitters; the result being that the teacher must operate and wear two transmitters and microphones simultaneously. Not a convenient situation for the teacher. Unfortunately, it is all too often the case that sound field systems are selected and purchased without consulting with an audiologist regarding compatibility with other assistive technology. Educational audiologists or deaf education con-

sultants may be required to troubleshoot and retrofit a sound field amplification system after-the-fact to implement the use of a child's personal FM system in the classroom. Ideally, the classroom teacher would only wear one FM transmitter which could transmit to other assistive technology used in the classroom, and the transmitter would be able to provide all the advanced features needed for students, including good noise management in the FM microphone and adaptive FM levels during periods of high ambient noise. At this time, the only personal FM/sound field system that allows this ease of compatibility is Phonak's Inspiro and Dynamic SoundField combination.

As class participation and question-and-answer learning increases in older grades, the starting FM gain or FM advantage may require adjustment. The use of a pass-around microphone may be too slow or awkward in a learning atmosphere that has lively student and teacher interactions, yet the child wearing the FM system needs to hear other students' voices in order to participate in the classroom discussion. Audiologists can make adjustments to the starting FM gain levels in a child's FM receiver, if the child indicates that they need a change in the balance between the teacher's voice level and classmates' voices. Reducing the FM receiver gain serves to reduce the compression applied to hearing instrument microphone inputs during times when teacher and classmates are talking quickly in a discussion or may even be talking over each other (simultaneous FM and hearing instrument microphone inputs). If the transmitter has Adaptive FM gain (AFMA) active and the ambient noise in the classroom is higher than 60 to 65 dB SPL, the adaptive function may override the reduced FM gain setting. This adaptive FM change may interact with the child's need to maintain adequate audibility of other voices in classroom discussion. However, no studies are available to evaluate if this interaction is a problem for FM users; it is thought that in some individual cases it may be a factor to consider if concerns or complaints are noted.

Secondary School and Beyond

When considering putting together personal FM systems for students in secondary educational settings, audiologists often must address the student's self-image in order to maintain acceptance and use of an FM system. Any additional piece of equipment or technology that singles the student out or draws attention may cause the student to reject use, even if the same student consistently wore and benefited from personal FM technology in previous years. Finding ways to make FM system use more acceptable and less outwardly obvious is a challenge that is addressed in consultation with the individual student. Some steps that may help include:

1. Evaluate classes where FM system use is most needed. This may include classes where the teacher's voice is difficult to hear and/or the background noise level is especially high, as well as in foreign language classes where vocabulary and pronunciation is more heavily dependent on listening alone. Although the student would likely benefit from using the FM system in all classes, the audiologist may need to compromise in order to gain cooperation from the student.
2. Reduce the visibility of the FM receiver to improve acceptance. The use of a Phonak iCom with a universal FM receiver, a Phonak MyLink+ or Oticon Arc device, which resemble mp3 devices, can disguise the look of the FM receiver. The iCom with universal FM receiver, MyLink and Arc receivers can also be worn under clothing to further reduce visibility without adding additional length to the hearing instruments worn at the ear.
3. Consider how to reduce disruption in class flow. The student must transfer the FM microphone/transmitter from class to class and deliver and pick it up from each teacher. The use of a lavaliere-style transmitter/microphone with an easily-adjusted neck strap can make the transfer process quicker and easier with minimal additional parts for the student to move between classes. The audiologist and student can work together to find an efficient and acceptable means of transferring the system between teachers and rooms.

Ultimately, the goal is to increase the student's independence and understanding of both their hearing loss and the amplification and other assistive technology that they use. This falls into the area of Transition or Access Planning, which goes well beyond FM system technology options but greatly impacts an individual's acceptance of amplification technology and their understanding of its use. Transition planning begins in secondary school to promote a student's self-advocacy for their own hearing health needs and to increase their independence in meeting those needs. Programs such as Phonak's GAP (Guide to Access Planning) are available to allow students, along with their parents, to learn more about the impact of their hearing loss and the services and technology available to meet their needs. Schroeder

and colleagues at Children's Hospital of Philadelphia (Schroeder, Rall, Montoya and Reyes 2010) provide an excellent summary of transition planning.

For students entering college or other post-secondary training, the use of an iCom with MLxi universal receiver combined with a lavalier-style transmitter can provide an extremely adaptable amplification system that allows bilateral FM input with one FM receiver, Bluetooth inputs for compatible cell phones, mp3 players and computers, and direct inputs to either the transmitter or iCom for a number of other digital and audio devices. The choice of directional settings on the transmitter allows increased options for use in and out of traditional lecture situations.

The ultimate goal when choosing an amplification system that includes FM technology is to provide clear, undistorted access to speech and other sounds for successful learning. The many advances in FM receiver and transmitter technology make that goal easier to achieve, but requires more decision-making on the part of both clinical and educational audiologists. Clinical and educational audiologists must work together and communicate consistently in order to provide hearing instruments and FM systems that work well together. FM technology choices may differ depending on where the system is being used and priorities will change as students progress through the educational system. It makes for an interesting journey along the pediatric age span.

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