Pediatric Frequency Modulated (FM) Amplification Fitting: Practical and Empirical Pre-selection Considerations

Andrew Stuart
School of Human Communication Disorders
Dalhousie Universtiy

Investigations into classroom acoustics have found that the normal classroom is an adverse listening environment for the hearing-impaired child (Bess & McConnell, 1981; Bess, Sinclair, & Riggs, 1984; Borrild, 1978; Crum & Matkin, 1976; Pearsons, Bennett, & Fidell, 1977; Sanders, 1965). The presence of excessive noise and reverberation can severely affect speech reception for these children (Finitzo-Hieber & Tillman, 1978; Gelfand & Hochberg, 1976; Gelfand & Silman, 1979; Gengel, 1971; Moncur & Dirks, 1967; Nabelek & Mason, 1981; Nabelek & Pickett, 1974a, 1974b; Yacullo & Hawkins, (1987). In fact, the commonly observed signal-to-noise ratios (S/N) of less than 15 to 20 dB have been found to add to an already existing deficit in auditory communication (Gengel, 1971).

As a means of overcoming noise and reverberation, the use of frequency modulated (FM) amplification systems has been advocated. A teacher's microphone/transmitter coupled with a student's receiver/amplifier, employing FM radio transmission, serve to improve the S/N for the child. This enhancement in S/N is attributed to the fact that the teacher's mouth is located at a distance of approximately fifteen centimeters from the microphone that delivers the signal to the the student's ear. For a child in the classroom with a hearing aid microphone alone the distance from the speech signal would be two or more meters. By being in closer proximity to the microphone the teacher's speech signal is increased relative to ambient noise. The magnitude of the improvement in S/N has been estimated to be approximately 20 dB (Pearsons et al., 1977). Reverberation effects are reduced due to the signal's close proximity to the microphone.

Several studies suggest that FM equipment enhances listening in typical classroom situations (Blair, 1977; Hawkins, 1984; Nabelek, Donahue, & Letowski, 1986; Picard & LeFrançois, 1986; Ross & Giolas, 1971; Ross, Giolas, & Carver, 1973). It has been noted, however, that "the way in which a system is obtained, introduced, accepted, and used may counteract any possible benefits" (Maxon, Brackett, & van den Berg, 1984, p. 2). One should recognize that these systems should be fit with the same regard for a child's individual amplification needs as is the case with personal hearing aids (HAs). "It would be inconsistent to demand precision for hearing aid fittings and to casually assign the same child an FM unit for school" (Bess & Sinclair, 1985, p. 980).

After assessment and diagnosis, and prior to selecting specific electroacoustic parameters for a child, "the audiologist will need to preselect a limited number of instruments for consideration on the basis of specific physical and electroacoustic criteria" (Seewald & Ross, 1988, p. 218). This type of pre-selection consideration is common practice in prescribing HAs and should be undertaken with respect to FM amplification. This practice becomes even more important with the increased complexity of and numerous options in classroom amplification systems (Hawkins, 1988).

The purpose of this article is to present many of the options currently available with FM amplification and to evaluate them in the light of practicality and, where possible, empirical evidence. This is not meant to be an exhaustive presentation, but rather a review of the more popular options and arrangements currently available. The aim of this paper is to help clinical audiologists become more aware of the unique problems and the specific decisions involved in selecting FM amplification for children. The article is divided into two parts: the first addresses concerns regarding the teacher microphone/transmitter, and the second part, the student receiver/amplifier.

Teacher Microphone/Transmitter

Three arrangements of the teacher microphone/transmitter are presently available. They include the lavalier style microphone/transmitter, the lapel microphone with belt-worn transmitter, and the boom microphone with headset arrangement and belt worn transmitter. The first two, at present, are the most popular.

The lavalier style microphone/transmitter is popular because of its 'pass around' convenience. This is an advantage in classrooms that have discussions with multiple participants. The teacher and students who are involved in speaking can easily handle the microphone and facilitate the hearing impaired child's participation. The major drawback of these microphones is that they are cumbersome when hung around the neck and tend to get in the way of teachers who do a lot of bending over when dealing with students at their desks. It is also important to instruct teachers to position the lavalier piece high on the chest in close proximity to the mouth to enhance the S/N.

The lapel microphone with belt worn transmitter is popular with teachers because it is less cumbersome to wear and offers greater mobility. In cases where teachers complain of clipping the microphone to their clothing, other arrangements are possible. They include hanging the microphone cord around the neck with the microphone clipped to the cord (ensuring the microphone is pointed up towards the mouth) or wearing the transmitter in a lavalier arrangement with the microphone clipped to the cord suspending the transmitter. Omnidirectional or directional lapel microphones are available. Some manufacturers provide directional microphones as standard practice while others provide them optionally at an additional cost. Hawkins (1984) has shown an improvement in S/N of 3.3 dB with the use of a directional microphone. When a directional microphone is employed it is important to instruct teachers to position the microphone correctly directed towards the mouth, to enhance the S/N.

The boom microphone transmitter/headset is a more novel approach with the microphone positioned just below the lower lip of the instructor via a headset. Mobility, as with the lapel microphone, is an advantage; however, the teacher may protest the head worn apparatus. One might suspect that there would be enhanced S/N at the microphone due to the proximity of the microphone to the mouth. On the other hand, the position of the boom may interfere with the students' visual perception of speech. To date there are no investigations in the literature that address these concerns.

Some FM manufacturers offer an FM level control potentiometer on the microphone/transmitters to allow the gain of the FM signal to be adjusted relative to the gain of the environmental microphone circuit. Such a feature is desirable because it allows for greater fitting flexibility for each child.

Student Receiver/Amplifier

Two general arrangements of the student receiver/amplifier are available. The first is the self-contained unit, the auditory trainer (AT), defined as any device incorporating a hearing aid (HA) and FM receiver. The second is the personal FM system (PFM) defined as any device utilizing a separate FM receiver coupled to a personal HA. It can be noted that ATs can be utilized as PFMs by disengaging the HA of the unit and coupling the receiver to a personal HA.

There is general consensus in the literature with respect to minimal performance criteria for a student's FM receiver/amplifier (Bess & Gravel, 1981; Bess & Sinclair, 1985; Boothroyd, 1981; Byrne & Christen, 1981; Ross, 1981, 1986; Ross, Brackett & Maxon, 1982; Sanders, 1981). Their criteria include: (1) an electroacoustically flexible system that can be adapted to the specific needs of individual children; (2) an external environmental microphone enabling child-to-child communication and auditory self-monitoring; (3) binaural microphones for reception of environmental signals; and (4) switch positions on units allowing for the choice of environmental reception only, FM reception only, or a combination of the two.

Most AT receivers manufactured today are equipped with controls for individual adjustment and changes in listening modes. They include: SSPL 90; FM gain or "trimmer control;" and varying switch positions for reception of environmental signals only, FM only, or a combination of the two. Some old units still in use (e.g., Phonic Ear 431) lacked an FM trimmer control. The absence of this control prevents one from matching the output levels (for the user) of the FM reception and environmental reception for two different input levels: 60 to 65 dB SPL to the environmental microphone and 80 to 85 dB SPL to the FM microphone (Byrne & Christen, 1981; Hawkins & Schum, 1985; Lybarger, 1981; Pearsons et al., 1977; Turner & Holte, 1985). The difference of 20 dB of output results from the signal source being located at different distances from the input microphone. If one is concerned with providing a consistent signal for different modes of reception, the difference in input levels must be attended to (Byrne & Christen, 1981). A consisent signal is assumed to be one in which the FM and environmental HA outputs are matched. If the input level is higher for the FM microphone than for the environmental microphone, the gain should be correspondingly lower in order to provide the same output (Byrne & Christen, 1981; Hawkins, 1984, 1987; Hawkins & Schum, 1985; Lybarger, 1981; Turner & Holt, 1987).

The environmental microphone arrangement on AT receivers is generally monaural or binaural; omnidirectional or directional; on the body or at ear level. Existing literature suggests an advantage for a binaural, at ear level, and directional microphone arrangement (for ear level applications) (Byrne & Dermody, 1975; Gelfand & Hochberg, 1976; Hawkins, 1984; Maxon, Brackett, Zara, & Ross, 1988; Maxon & Mason, 1977; Moncur & Dirks, 1967; Mueller, 1981; Nabelek & Mason, 1981; Nabelek & Pickett, 1974a, 1974b; Yacullo & Hawkins, 1987). Some AT receiver models employ directional microphones for the chest worn receivers (e.g., Phonic Ear 461). No data are available, however, on performance advantages for such a configuration. A reduction of clothing noise has been suggested (Phonic Ear Ltd., personal communication, October, 1987).

Generally, a decision to fit a child with an AT tends to be based upon age and degree of hearing loss. Children below the junior high school age tend to be less concerned with the cosmetic appearance of the chest worn receiver/amplifier coupled with standard ear mold and button receivers. There is the advantage that when the FM system breaks down, the user usually has personal home amplification that can be used as a backup. The malfunction of FM systems has been documented (Bess & Sinclair, 1985; Bess et al., 1984). AT receiver arrangements may be more attractive for the "left corner" profound hearing loss in that they tend to provide more low frequency amplification when compared to a behind-the-ear hearing aid in a PFM arrangement. The binaural advantage may be reduced in the AT configuration with the close spacing of the environmental microphones when compared to the PFM configuration (with binaural behind-the-ear HAs) unless ear level microphones are employed (Byrne & Dermody, 1975; Maxon et al., 1988; Maxon & Mazor, 1977).

Personal FM receivers are an option for those who have personal HA amplification (presumably behind-the-ear HAs). Providing the individual's HA has SSPL90 and tone controls, full electroacoustic flexibility is complete with the provision of an FM volume control wheel on the PFM receiver (standard on most models). SSPL90 and frequency tone controls are usually not present on PFM receivers. In cases where an AT receiver is being utilized as a PFM (after disengaging the HA portion of the unit) the tone and SSPL90 controls can be used for greater fitting flexibility with the FM reception.

Coupling the PFM to the HA can be achieved by either electrical, induction, or acoustical means. Electrical coupling, more commonly known as direct audio input, involves a 'cord and boot' attachment to the HA. Induction coupling can be achieved with either a neck loop or silhouette inductor, with the personal HA worn in the telecoil position. Acoustical coupling is for the most part non-existent today and will not be addressed.

Hawkins (1984) reported that there is no advantage in performance for either direct audio input or induction coupling. The transduction of a signal through either induction or direct audio input to a HA has been shown to increase internal noise and harmonic distortion (Hawkins & Schum, 1985; Hawkins & Van Tasell, 1982). Overall more favorable results have been obtained with direct audio input as opposed to loop or silhoutte induction. The effects of the degradation of signal and S/N on speech perception would depend on an individual's hearing loss and speech recognition ability in noise (Hawkins & Van Tasell, 1982). The neck loop may be more appealing cosmetically to an older child becauses it is less noticeable compared to direct audio input and silhouette cords. Small changes in the physical coupling of an HA to a silhouette conductor and changes in head and neck orientation with a neck loop may change the strength of the electromagnetic field encircling the child's head. These changes would significantly affect FM input (Hawkins & Schum, 1985). Considering reduced internal noise and harmonic distortion and changes in FM input direct audio input has been suggested as the method of choice (Hawkins, 1984).

Regardless of the type of coupling one chooses, it cannot be assumed that the HA frequency response will be preserved when it is connected with the FM system (Hawkins & Schum, 1985; Hawkins & Van Tasell, 1982; Thibodeau, 1987). Each FM system should be evaluated in conjunction with a child's personal hearing aid.

At the time of hearing aid selection, audiologists should be aware of the different operating capabilities of different HAs if the device chosen is to be used in conjunction with a PFM. For example, some HAs are limited in their choice of listening modes when coupled to PFMs and cannot switch between HA-only, FM-only, and a combination of the two. Hawkins (1984) has shown that an inability to switch out of the environmental FM-reception mode to FM-only mode reflects a 20% decrease in speech recognition. For some HAs without this capability (and not available on the boot) modifications are possible from the manufacturers at the time of purchase of the HA, at minimal or no additional cost. Some HAs with switch modifications may lose the telecoil, however. It is important to inquire about this with the manufacturer. For those HAs that are to be coupled on induction, it is important to assess if they have a telecoil position only or the microphone-telecoil combination. The former would restrict the child to FM reception only and eliminate environmental and auditory self-monitoring reception. Some PFMs provide an environmental microphone (e.g., Phonic Ear 475) for this purpose. Two problems are apparent with this arrangement. One is that the binaural microphone advantage is lost. The other is that the transmitter must be worn on the chest for the best reception. This latter arrangement may be objectionable for the older user.

Pilot lights for the battery charge and FM reception are features worth considering for both the transmitter and receiver of any FM system. Bess et al. (1985), in a report on FM units which failed a trouble-shooting inspection in a school population of users, noted that 21% of teacher and 9% of student units had battery failure. Further, 86% of teacher and 30% of student units had broken antennas. This high incidence of failure suggests that many systems without battery or FM reception indicator lights may be non-functioning during daily use without the knowledge of the child's teacher unless regular listening checks are performed. This would be a greater possibility with the younger and/or nonverbal FM user.

Other FM pre-selection considerations may include the FM receiver's ability to be tuned to different frequencies; capability of accepting auxiliary input from the audio sources; recharging capabilities; cost; manufacturer's warranty; service contracts; availability; and simplicity of use. All of these factors need to be considered for an individual user.

In conclusion, it can be noted that although the benefits of FM amplification are well recognized, generic FM amplification fitting for school children is far from a reality. It behooves the audiologist to be acutely aware of the complexity and numerous options available with FM amplification. Critical evaluation of FM units and HAs before their recommendation and fitting is necessary if one is to provide the best possible amplification and listening advantage for the child. This article has addressed a number of considerations worth noting in fitting FM amplification for the pediatric client.

Author Notes

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Address all correspondence to:
Andrew Stuart
School of Human Communication Disorders
Dalhousie University
5599 Fenwick Street
Halifax, NS B3H 1R2

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