COMPARISION OF INDIGENOUS
AND IMPORTED FM SYSTEM

REG. NO. M9508

An Independent Project submitted as part fulfilment of first year Master's Degree (speech and hearing) to the University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING :
MYSORE - 570 006

CERTIFICATE

ThiS is to certify that this Independent Project titled **"Comparison of Indigenous and Imported FM systems"** is the bonafide work done in part fulfilment for the First Year Master's degree in Speech and Hearing of the student with Register Number M9508.

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May 1996

CERTIFICATE

This is to certify that this Independent Project titled : **"Comparison of Indigenous and Imported FM systems"** haB been prepared under my supervision and guidance.

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DECLARATION

I hereby declare that this Independent Project titled : **"Comparison of Indigenous and Imported FM systems"** is a study of my own effort under the guidance of **Dr. (Miss) S. Nikam,** Professor and Head of the Department of Audiology at All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

Reg. No. M9508

Mysore
May, 1996.

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INTRODUCTION

Ancient Sanskrit literature has defined man as being bound to this world by five of his senses - vision, hearing, smell, taste and touch. Although all of these are important for a human being, the sense of hearing, due to its unseverable connection with speech, forms an intrinsically important link in the life of man. Hearing, thus, helps in forming bonds between people as it is an inseparable part of the speech chain.

The importance of hearing is felt, as for most other things, most severely in its absence. A hearing impaired child bears testimony to all the infinite ways in which hearing is woven into our lives.

Due to the above mentioned effects of a loss of hearing, rehabilitation of the hearing impaired has become a major area of concern, especially to the professionals dealing with the handicapped in India. One of the foremost considerations in any of these programs is of primary amplification. According to Ross (1975)

'Amplification is the only therapeutic measure that focuses directly on the primary cause of the handicap, that is, the hearing loss itself .

Ideally an amplification system should reduce background noise and enhance quality of speech. It should be cosmetically appealing, easy to handle and adaptable to all listening environments while retaining the technical specificatione of high fidelity and minimal distortion. Presently, however, no such device is in existence. The choice is restricted to

Personal (wearable) aids

body level (air & bone conduction)

ear level (air & bone conduction)

- x spectacle type
- x behind the ear
- x in-the-ear
- x in-the-canal

Educational aids

hardwire systems

disk type trainers

loop

wireless

- x FM loop
- x FM
- x Infrared

Direct signal input

Sensory Aids

Vibrotactile aids etc-

Electrode implants

(The last 2 are more often considered as aids rather than as amplification systems due to their transducing action).

Amongst all the above mentioned devices the hearing aid has been the most widely used. But although the hearing aids are more easily available, and economically more suited, especially in the Indian context, they have a major drawback in the fact that they tend to amplify both the signal and the noise. This creates a lot of problems for the hard of hearing especially those who have to function in a high background noise environment (eg. factories, schools, indoor stadiums, theatres, etc) One device which successfully overcomes this problem is the FM system.

What is an FM System?

An FM or 'frequency modulated' system works on the principle of modulation of the audio signal onto a carrier wave which is accomplished at the transmitter worn by the speaker. This is then transmitted to the receiver worn by the listener. It may be coupled directly (direct input and acoustic coupling) or indirectly via induction (neckloop or silhouette).

Applications of FM system :

i) In classrooms - May be used in integrated and segregated classrooms and also as an auditory trainer. Adjacent classrooms can have their own systems without interference.

   It may also be used with children with central auditory processing deficits and the learning disabled (Stach, Loisette and Jerger 1987).

Children with unilateral loes, mild loss or other developmental disabilities have also found this effective (Cargill, Flexer 1991; Bess 1986; Flexer, Millin and Brown 1990).

ii) Employment - it improves communication at meetings and for one-to-one situations. A conference mic can allow greater participation.

iii) Infants - language stimulation for the severely or profoundly impaired population has been more effective using this system.

iv) For travel - especially travel requiring listening to tour guide presentation can be improved.

v) For adult education - mainly for continuing adult education in lecture hall settings etc.

vi) In arenas, stadiums, theatres and places of worship.

Advantages of the FM System :

The FM system addresses the following needs : it provides a better S/N ratio, improved hearing in reverberant conditions, improved reliability, flexibility, greater fidelity and portability. It can be used indoors or outdoors in adverse weather conditions. It can even be used with obstructors (eg : across rooms). The transmission is constant from 100 - 300 feet. It also improves mobility and elimination of noise interference by overspill.

As the use of FM system becomes more popular there is a greater need for a more efficient system of prescription of these systems. One of the methods of prescription which eliminates the need for patient participation and cooperation is prescription by electro acoustic characteristics measurement.

Functional and insertion gain measurements have been used widely in literature, mostly for classification and prescription of hearing aids. This concept has been extended to other amplification devices viz. the FM system.

Need for Present Study :

The present study deals with a comparison between two FM systems to evaluate their performances. It is meant to bridge a gap between the user's needs and the prototype the manufactures are creating. It will also be able to provide the user with an adequate measure for purchasing a system.

REVIEW OF LITERATURE

In spite of the widespread use of FM systems in educational and other environments, little attention has been directed toward specific methods of measurements and fitting. Often the typical methods UBed with personal hearing aids have been employed. These approaches may be appropriate in some aspects, but distinct limitations are present.

Although FM systems are amplification devices similar to hearing aids, there are some distinct differences which need to be taken into account in developing measurement strategies. First, and perhaps most important, the input level of speech to the FM microphone is more intense than to the hearing aid microphone. With the FM microphone appropriately located 6 to 8 inches from the talker's mouth, the overall level of speech is approximately 80 to 85 dB SPL (Cornellise, Gagne & Seewald, 1991; Hawkins, 1984; Lewis, 1991; Lewis et al., 1991). This is 10-20 dB more intense than the typically assumed 60 to 70 dB SPL input to the microphone of the personal hearing aid from one to two meters. This fact has important implications in the assessment and fitting of FM systems. If output measurements are being made to adjust and fit FM systems, then typical input levels should be employed. This is particularly important given that most FM microphone transmitters employ some type of input compression. The gain and output of the FM system may be quite different if lower level signals, which are not representative of the speech input to the FM microphone, are , uaed in the measurement procedure.

A second issue relates to the increased complexity of the FM systems compared to hearing aids. Many FM systems have several microphone input possibilities. There is a talker's microphone as well as an environmental microphone(s), which can be located either at ear level or on the body-worn FM receiver. There may be one or two environmental microphones, and they may be omnidirectional or directional. It is important that each input channel in the FM system be evaluated for proper functioning and that the microphones be positioned in the proper manner. If only the FM module needs to be assessed it is generally suggested that all others be disconnected.

In a similar vein, the FM system may have more than one volume control wheel (VCW). Some units have one VCW for the FM signal and one for the environmental microphone(s). On personal FM systems, there will be one VCW for the FM system and one for the personal hearing aid. It is important that careful thought be given to the setting of these VCWs, as certain combinations can produce undesired results (Hawkins & Schum, 1985; Hawkins & Van Tasell, 1982; Lewis, 1991; 1992).

Finally, modifications must be made in some testing procedures to account for the way certain systems are physically arranged on the client. For instance, if personal FM system with a neck loop is to be evaluated in a 2 cc coupler, then the hearing aid (attached to the coupler) and neck loop must be located appropriately on the body (preferably the client) if the measurements are to be valid.

Types of Performance Measurements :

There are three baBic types of performance measurements that can be used with FM systems. First, performance measurements can be made by adjusting the FM system's electroacoustic characteristics in a 2 cc coupler. Second, a measure of real-ear performance of the FM system can be made. Third, an assessment of speech recognition ability and/or improvement with the FM system can be accomplished.

Electroacoustic **Measures** in a **2** cc Coupler for Fitting **and** Adjustment of FM System :

The lack of standards for measurements extends even to coupler specifications for electroacoustic characteristic measurements. Due to this, various authors have utilised the specifications for hearing aidB for these measurements. Lybarger (1981) has given a few guidelines regarding the same. For insert or button type earphones, the 2 cc coupler as standardized in American National Standards 53.7 - 1973 has been suggested as the best. For supraaural earphones the National Bureau of Standards 9-A coupler has been considered. However no details for receivers with headband and inserting into the ear) have been discussed (for details of measurement technique see Appendix I).

Due to the existing vacuum of data regarding specifications about use of couplers the HA2 coupler has been utilised most often, especially when two disparate types of receiver systems are being compared.

Real-Ear Measurements for Fitting and Adjustment of FM Systems :

There are two approaches that have been employed to fit and adjust FM systems using assessment of real-ear performance : Functional gain or aided sound-field thresholds, and probe-microphone measurements. While behavioral measurements of real-ear performance such as functional gain have been recommended by some investigators, several distinct limitations of this approach have been described recently. The major problem with the functional gain approach is that the input levels to the FM microphone at the aided threshold will typically be quite low during the measurement procedure. These lower input levels will not be representative of the talker's voice entering the FM microphone during actual use of the FM system. These input level differences, combined with the fact that most FM microphone-transmitters incorporate input compression, made the aided sound-field threshold values difficult to interpret. While the threshold values would represent the lowest intensity signal that the client could detect with the FM system, they would lead to overestimation of the amount of gain the FM signal would be receiving and the sensation level at which speech would be present.

Realization of these limitations of behavioral testing and the inability to assess the maximum output of the FM system with threshold measurements has led to an increasing emphasis on the use of probe-microphone measurements. Using this approach,the real-ear gain/frequency response and maximum output can be assessed with realistic input levels (for details Bee Appendix II & IV).

Bryne (1981) has emphasised on the need for measurement of the preferred listening level (PLL) instead of the hearing threshold or most comfortable level for prescription of FM systems. Although some authors still prefer to prescribe hearing aid gain on the basis of the hearing loss, this has been found to cause overamplification especially in the case of sensory neural (SN) hearing cases. On an average, for SN loss cases, a 10 dB rise in hearing threshold (HTL) requires only a 5 dB increase in gain (Brooks, 1963; Millin, 1973; Boorsoma and Courtay, 1974; McCandless, 1976; Byrne and Tonnison, 1976; Martin Grover, Worall & Williams, 1976; Schwartz and Larson, 1977). Various authors have discussed a variety of formulae to specify the gain characteristics for amplification. Duffy (1990) has discussed the various merits and demerits of the formula used with regard to amplification.

The criterion of phoneme audibility, recognition and speech perception have been used by Duffy to specify the amount of gain desirable at various frequencies. He has compared the Berger, POGO and NAL formulae especially with respect to the above. He concludes that for providing optimum gain the formula must allow the output curve to follow the speech spectrum rule i.e, a gradual reduction in intensity between vowels and unvoiced consonant is compensated by an increase in intensity at higher frequencies. On the basis of type, degree, most comfortable level (MCL) and loudness discomfort level (LDL), speech reception threshold (SRT) and phoneme recognition ability he suggests the use of Berger and POGO to be most appropriate. NAL, while not faithfully following the speech spectrum rule, also entails complicated computational procedures.

Speech Recognition Testing with FM Systems :

It is often necessary and/or desirable to assess the speech recognition ability of a client with an FM system. It may also be important to compare such performance with a personal hearing aid(s) (for details see Appendix III).

METHODOLOGY

The methodology will be discussed under the following subsections

i) Subjects
   - selection criterion
   - no. of subjects

ii) Instrumentation

iii) Test environment

iv) Instructions

v) Procedure
   - Calibration
   - Procedure of testing

vi) Data recording

Subjects Selection

Criterion :

Moderate or Moderately severe hearing loss cases with 'A' type tymprograms were selected All the cases had been screened at AIISH with in the past 6 months. The age group was not specified. The subjects selected were between 5 years - 75 years with a mean age of 31.5 years.

No. of subjects :

A number of 31 ears were selected to make statistically significant conclusions.

Instrumentation

EXPT I :

The FONIX 6500 - C Real-Time Hearing Aid Analyser with software version V 3.09E/64K/000097f7-93.08.03 was used. Along with these the standard accessories for the FONIX 6500-C were also used. These were

i) Instrumentation Microphone (M1550E or M1550) a pressure type condenser microscope with 14 mm diameter.

ii) Direct Access HA-1, 2cc coupler (coupler dimensions as per ANSI S3.7 - 1973).

iii) Standard HA-2, 2 cc coupler (coupler dimensions per AN£ S3.7 - 1973).

iv) QUIK-PROBE option providing real time, real ear testing i: automatic or manual mode with probe and referenc microphone, loudspeaker with floor stand, velcro headbook ear hanger and cables, also a loudspeaker swivel arm for suspension of the same.

The two systems compared were

a) Aid 'A' with FM module, a foreign universal listening system. This system had a provision for a tuning dial (72-76 MHz), it had a provision for an environmental mic volume control and a volume control for the module in addition to a tone control mechanism. Both the transmitter and the receiver need to be charged prior to usage.

b) Aid 'B' an indigenous FM system (an experimental prototype group system) with a transmitter and 12 sets of receivers. This battery operated instrument utilises 4 cells (pentorch) for the transmitter and 2 for the receiver. The receiver is equipped with an on-off switch and a volume control.

EXPT II :

The instruments utilised were -

A Madsen 0B822 audiometer with TDH - 39 earphones calibrated to IS standards. MD 402-K microphone was also used. For free field testing cosmic COVOX 4500 loudspeaker with cosmic CD100 Delux MKII amplifier was uBed.

Test Environment

EXPT I :

All testing was carried out in a quiet sound treated room. The ambient noise levels at all frequencies were within the valueB specified by IS standards.

EXPT II :

The perceptual evaluation was carried out in a 2 room situation which was also sound treated. The ambient noise levels at all frequencies were within the values specified by IS standards.

INSTRUCTIONS

EXPT I :

Cases were instructed not to move their heads or swallow.

EXPT II :

A picture identification task or a spondee repetition task was given depending on the age and speech and language skills of the case being tested (Details of both included in appendix III). The presentation level was kept constant at 35 dB HL.

An additional evaluation of the speech detection threshold

Procedure

Calibration :

Due to frequency response irregularities in all sound chambers the 6500-C was leveled for each frequency each time the instrument was turned on. The following procedure was used.

1. The power was turned on by pressing the upper edge of the POWER switch, located on the lower right side of the front panel. The green LED 1ighted up when the instrument was switched on.

2. The video monitor was turned on by pressing the power switch at the lower right corner of the screen. Brightness contrast controls for proper viewing were adjusted.

3. The FONIX logo appeared with the software version and option code numbers on the screen.

4. The microphone was placed on the left side of the sound chamber, with the microphone grill over the reference point. The sound chamber lid was closed.

5. The (LEVEL) button, (on the far right side of the front panel, just above the POWER switch) was pressed to start the leveling sequence.

6. After a few BecondB, the video monitor displayed a graph with a straight line across at 0 dB, indicating that the chamber had been leveled. The process was not repeated unless the instrument was turned off.
(According to specifications in FONIX operator's manual)

Procedure for testing

Testing

Experiment I :

Coupler measurements

HA - 2 coupler

i) **For Aid '**A'

1. The receiver set was assembled by connecting the headset to the receiver.

2. The headset was coupled to the coupler using FUNTAK this was placed in the test chamber. The chamber was closed.

3. The procedure was begun by keeping the volume control setting in 'full on' and pressing 'start'.

4. The output curve, gain curve and distortion data was recorded.
(Note all measurements were done in SINE mode)

ii) For Aid 'B'

1. The FM system was assembled by connecting the receiver and cord to the receiver instrument and the microphone with the transmitter.

2. The receiver neck loop was placed around the 'receiver instrument'.

3. The instrument was leveled and the receiver was coupled to the coupler and placed in the test chamber. The chamber was closed.

4. The test procedure was begun by keeping the volume control on 'full on' and pressing 'start'.

5. The output curve and the gain curves were recorded.

6. The distortion data was also recorded.

(Note all measurements were done in the SINE mode)

Real Ear Measurement

1. The instrument was leveled and the probe tube was placed in the ear canal.

2. Mode was set to 'sine', i/p to 80 dB and the output limiting system was switched off.

3. REUR (Real Ear Unaided Response) was recorded by depressing the button marked 'continue/start stop' and recorded as Ref.1 the multicurve option.

4. The patients audiogram was fed in after recalling the 'REAR' option.

5. The formula POGO was selected using the cursor.

6. REAK for Aid A and B were recorded using the multicurve option as curves 2 and 3.

7. Adjustments in volume control were done to match the target curve.

8. The two curves were subtracted and the difference was obtained- It was stored as curve 1.

9. Harmonic distortion data was obtained for all the curves independently and also for the subtracted curve.

10. In case of a necessity for a print out, 'label' & 'CRT' were depressed.

Experiment *2:*

Perceptual evaluation

A. Without amplification :

Speech recognition scores at 35 dBHL were obtained for a picture pointing or spondee repetition task. Speech detection thresholds were also found.

B. With amplification :

With each of the systems in turn at presentation level 35 dBHL, speech recognition scores were obtained for the score material. For adults spondees were used. Speech detection thresholds with both the adis were found.

For adults cases information regarding intelligibility and clarity, distortion and personal preference was col looted.

Data Recording

The surve were stored on hard disk and a print out was taken. Distortion data wasa compiled in a tabular column.

RESULTS AND DISCUSSION

Statistical analysis using 't' test was done on both the electroacoustic and insertion gain data. The concised results are presented in subsequent sections in tabular columns.

Electroacoustic Characteristics :

TABLE I : GAIN COMPARISON OF THE TWO AIDS

	FREQUENCIES						STATISTICS		
	500	1K	2K	4K	6K	8K	MEAN	SD	t ratio
Aid 'A'	10.1	21.3	24.5	5.3	4.9	7.3	10.6	9.89	1.59
Aid 'B'	7.3	17.3	21.11	3.3	7.2	4.1	7.65	2.46	
Difference Curve	2.8	4.0	3.4	2.1	2.3	3.2	2.95		

TABLE II : DISTORTION COMPARISON OF THE TWO AIDS

	FREQUENCIES			STATISTICS		
	500	1K	2K	MEAN	SD	t ratio
Aid 'A'	0.3	0.5	0.4	0.4	0.08	2.96
Aid 'B'	0.8	0.9	1.5	1.07	0.30	

By using the 't' test no significant difference at either level of confidence was calculated [t ratio's being 1.59 (table I)] for the gain curve. The electroacoustic characteristics of the 2 hearing aids showed a distinct difference in terms of both gain and distortion measurements. Aid 'A' had a relatively higher value of gain at all frequencies with a peak gain at 2KHz. This could definitely make it more appropriate for prescription to cases requiring a slightly higher gain. These measurements (in Aid 'A') were made with the environmental microphone off. This was done more because of the necessity of comparison of this aid with Aid 'B' without contamination of results by errors or alterations induced due to coupling between the environmental microphone and FM the module (Hawkins and Schum, 1985; Hawkins and Van Tasell, 1982; Turner, 1985). Thus although there was a difference in the gains consistently it was not statistically significant.

The distortion data however did show a significant difference at the 0.05 level indicating that the distortion value of Aid B is definitely of grave concern.

Insertion gain measurements

TABLE III : GAIN COMPARISON OF THE TWO AIDS

	FREQUENCIES						STATISTICS		
	500	1K	2K	4K	6K	8K	MEAN	SD	t ratio
Aid 'A'	7.7	15.3	17.0	4.9	3.8	6.0	9.11	5.14	0.04
Aid 'B'	6.5	12.8	15.0	4.0	3.0	5.8	7.85	4.54	
Difference Curve	0.7	2.5	2.0	0.9	0.8	0.2	0.2		

TABLE IV : DISTORTION COMPARISON OF THE TWO AIDS

	FREQUENCIES			STATISTICS		
	500	1K	2K	MEAN	SD	t ratio
Aid	0.45	0.62	0.6	0.56	0.08	
Aid	0.84	0.92	1.6	1.12	0.34	2.26

The tables III & IV did not show a significant difference of means at 0.05 or 0.01 level. (t ratio's being 0.041 and -2.26 for the tables respectively). On inspection of the distortion data at 0.1 level the data was significantly different, this was always in favour of Aid 'A'. The volume setting for Aid 'B' was consistently kept higher for the same subjects when compared to Aid 'A'.

We have discussed the objective measurement of gain and distortion, a subjective assessment of the individual's response with respect to clarity, comfort and intelligibility was also obtained from the adult cases. All of them preferred Aid 'A'. They used terms like 'more clear', 'less noisy', 'feels better', 'hear better' etc. when asked for reasons.

Aid 'B' was observed, to have some additional problems like faulty switches, repeated loose contacts and disconnections at lower volumes. It required constant care and regular maintainance. It was thus not very reliable.

Limitations and Implications of the study:

Most of the limitations of the study stem from a vaccum in standardization of testing procedures for FM systems. Thus in comparison across studies, generalizations must be made keeping in mind the various procedures adopted.

While discussing the implications of the study for further research an important factor viz. a higher full-on-gain at lower frequency and its effect on patients with high frequency losses but normal thresholds at lower frequencies needs to be investigated.

Also the field effectiveness of the instruments can be verified by using them in a clinical set up and thus making careful observations.

SUMMARY AND CONCLUSIONS

The study was undertaken to compare the characteristics of 2 FM system.

Aid 'A' - a imported make with FM module cum environment microphone

Aid 'B' - an Indian group FM system.

Electroacoustic characteristics, insertion gain measurements with respect to gain and distortion were made on 31 ears with moderate to moderately severe SN loss cases with no middle ear pathology. Subjective assessments by all adults were also obtained regarding their preference among the aids.

Both aids were found to be comparable in terms of gain and distortion characteristics statistically. (Aid 'B' showing consistently larger values for distortion and lower values for gain). The subjective assessment, however, clearly indicated listener preference for Aid 'A' due to better intelligibility, lesser noise component and clearer quality. Aid 'B' showed a need for regular maintainance especially with regard to loose contacts, inability to operate the instrument at low volumes and a faulty construction of the battery compartment. It, also showed a lesser amount of gain at lower frequencies which may be an aBBet during amplification for high frequency loss cases.

APPENDIX - I

Outline for FM System Adjustment Using 2 *cc* Coupler Measurements

cited in ASHA '91 'Recommendations for measurement of performance of FM Systenis'

1. Verify through electroacoustic measurements and/or probe-microphone measurements that the client's hearing aid is functioning properly and has been fit appropriately for the hearing loss.

2. Obtain 2 *cc* measurements on the client's personal hearing aid.

   a. Obtain an SSPL90 curve usign a 90 dB SPL swept pure tone with the hearing aid VCW full-on.

   b. Adjust the hearing aid VCW to the use position. Using a 70 dB SPL speech-weighted noise or a 60 dB SPL swept pure tone, obtain an output (not gain) curve in the 2cc coupler.

3. Set up the FM system for 2 *cc* coupler measurements (see figure 1-A).

   a. Place the FM microphone in the calibrated position in the test box and close the lid.

   b. With the FM receiver outside the test box, set the receiver for FM only reception. Attach the button or

(i)

behind-the-ear (BTE) receiver to the HA-2 2 *cc* coupler. Maintain a minimum distance of 2 ft between the FM transmitted and receiver.

c. If a personal FM system is used, connect the FM receiver to the personal hearing aid (also located outside the test box) via the coupling method that the client will use (direct audio input, neck loop, or silhouette). If a neck loop is used, the hearing aid should be placed on the client (or other person *of* similar size, if possible, if the client is not available) and the earhook connected to the HA-2, 2cc coupler (or individual earmold connected to the HA-1 2 *cc* coupler) which is held next to the client's ear (see Figure 1-B).

4. Adjust the FM system SSPL90 to match the personal hearing aid SSPL90.

   a. Turn the FM receiver VCW full-on (also turn the personal hearing aid VCW full-on if a personal FM system is being evaluated) and obtain an SSPL90 curve with a dB SPL pure-tone sweep.

   b. Adjust the FM systems SSPL90 control until the SSPL90 curve most closely matches that of the personal hearing aid (# 2 above).

(ii)

5. Adjust the FM system output and frequency response to match the personal hearing aid.

   a. Using a 85 dB SPL speech-weighted noise or a 75 dB SPL swept pure tone delivered to the FM microphone in the test box, adjust the FM receiver VCW and tone control(s) until the 2 *cc* coupler output(not gain) most closely matches the output obtained with the personal hearing aid (# 2b above).

   b. With a personal FM system, leave the hearing aid VCW and tone control(B) at the user setting and adjust only the FM receiver VCW and tone control(s) to obtain the closest match to the personal hearing aid alone response (#2b above).

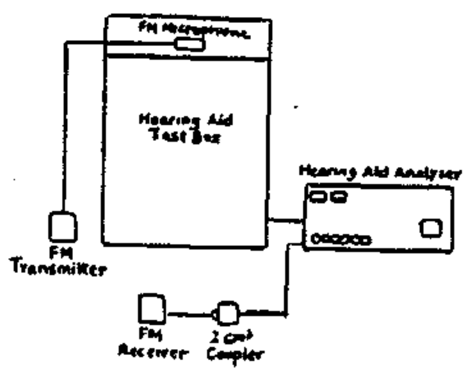


Figure 1-A. Physical arrangement for 2 *cc* coupler measurements of FM systems when measuring FM transmission mode only. The FM receiver may be attached to the HA-2 2cc coupler via an external

(iii)

button receiver. BTE receiver or via a personal hearing aid if direct audio input or a silhouette inductor is utilized (Adapted form Thibodeau, 1992).

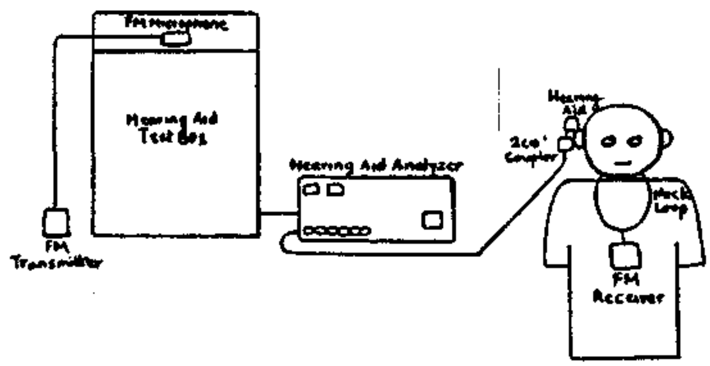


Figure 1-B. Physical arrangement for 2 *cc* coupler measurements of the FM system connected to a personal hearing aid via a neck loop. The hearing aid is set to the "T" position and the environmental microphone(s), if present, on the FM system are deactivated if possible.

APPENDIX - II

"Outline for FM System Adjustment Using Probe-Microphone Measurements" ASHA '91.

cited in "Recommendations for measurement of performance of FM Systems".

1. Determine a set of target real-ear maximum output and frequency response values through either

   a. using existing real-ear measurements obtained from an appropriately fit personal hearing aid.

   OR

   b. a published amplification selection-scheme, e.g. DSL (Seewald et al, 1991).

2. Prepare the test environment for probe-microphone measurements.

   a. The placement of the FM microphone in sound field will depend on the specific probe-microphone system. See figure 2-A for a possible arrangement if the probe system uses an off-line (or stored equalization method. During equalization, the reference microphone is placed at the location of the probe microphone. During the measurements the reference microphone is disabled. If the system uses a controlling microphone for on-line equalization, it can be located near the FM microphone, as shown in Figure 2-B.

b. Place the probe tube in the *ear* canal at an appropriate location, connection the FM system (set to FM only) to the client via the coupling method that will be used.

3. Adjust the FM system maximum output to the desired position.

a. Set the maximum output control to the minimum position.

b. Set the FM VCW to the highest level before feedback (and the client's hearing aid VCW to a similar position if it is a personal FM system). Obtain a measure of the Real Ear Saturation Response (RESR) by introducing a 90 dB SPL swept tonal signal and measuring the output in the ear canal. (NOTE : Extreme care should be exercised in making this measurement so as to prevent excessive output and/or discomfort; the output control should be set to the minimum position for the first measurement). An alternative to directly measuring the RESR has been outlined by Sullivan (1987) and described by Hawkins (1992, 1993).

c. Adjust the output control until the RESR most closely matches the personal hearing aid RESR or the desired RESR targets.

4. Adjust the FM system real-ear output and frequency response for the FM signal to match the personal hearing aid values or the desired real-ear values.

a. Using an 85 dB SPL speech noise or a 75 dB SPL swept tonal signal through the FM microphone, adjust the FM receiver VCW and tone control(s) until the desired real-ear values are most closely matched.

b. With a personal FM system, leave the hearing aid VCW and tone control(s) at the user setting and adjust only the FM receiver VCW and tone control(s) to obtain the closest match.

5. Measure the real-ear output and frequency response of the environmental microphone(s).

a. Turn off the FM microphone and place the client in the sound field as for probe measurements with a personal hearing aid.

b. Measure the real-ear output using a 70 dB SPL speech noise or a 60 dB SPL swept tonal signal. If only one VCW exists on the FM receiver and it controls both the level of the FM signal and the environmental micro phone(s), then a decision must be made as to where the single setting will be. If separate VCWs are present for the FM signal and environmental microphone(s), then the environmental microphone VCW can be adjusted to an appropriate level relative to the FM signal (see Lewis et'al., 1991 and Lewis, 1993, for more discussion of this issue).

(vii)

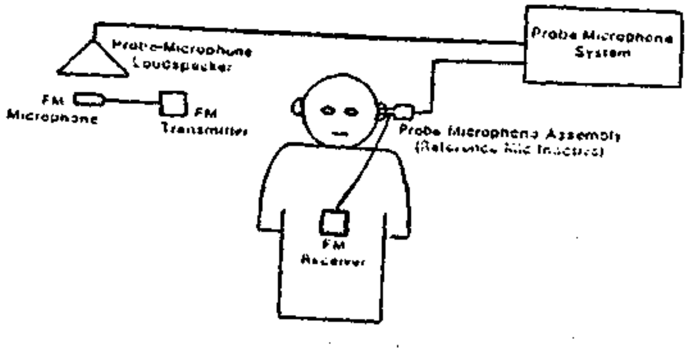


Figure 2-A. Physical arrangement for probe-microphone evaluation of FM system for the FM-only mode when the probe-microphone system uses an off-line (or stored) equalization method. During the actual probe measurements the reference microphone is disabled.

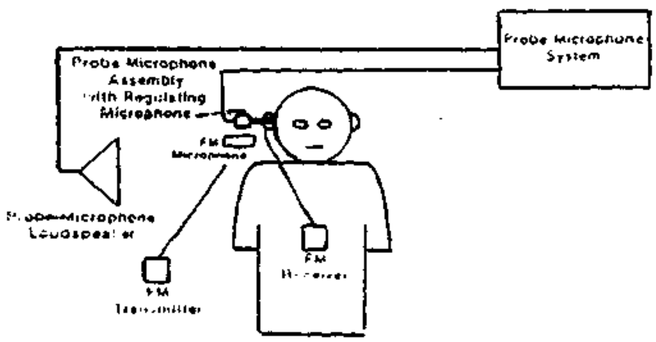


Figure 2-B. Physical arrangement for probe-microphone evaluation of FM system for the FM-only mode when the probe-microphone system uses a controlling microphone for on-line equalization.

APPENDIX - III

Speech Recognition Measures with FM Systems and Personal Hearing Aid(s)

cited in "Recommendations for measurement of performance of FM Systems".

1. Select a speech recognition test that is age and language appropriate for the client.

2. Place the hearing aid(s) on the client and set up the arrangement shown in Figure 3-A-

    a. Speech is at 55 dB HL (68 dB SPL) and noise at 50 dB HL (63 dB SPL), producing a S/N ratio of +5 dB. The loudspeakers are located at plus and minus 45 degree azimuths.

    b. Obtain a speech recognition score.

3. Place the FM system set to FM only on the client and set up the arrangement shown in Figure 3-B.

    a. Speech is 70 dB HL (83 dB SPL) and noise is 50 dB HL (63 dB SPL), producing a s/N ratio of +20 dB at the FM microphone. The loudspeakers are located at plus and minus 45 degree azimuths.

    b. Obtain speech recognition score.

4. If a speech recognition measure is desired for FM system with environmental microphone(s) active, set up the arrangement shown in Figure 3-C

   a. Speech is 55 dB HL (68 dB SPL) at the client's location and noise at 50 dB HL (63 dB SPL), producing a S/N ratio of +5 dB at the environmental microphone(s).

   b. The FM microphone is positioned in front of the speech loudspeaker at a location designed to produce 83 dB SPL speech input to the FM microphone.

   c The environmental microphone(s) on the FM system are activated.

   d. Obtain a speech recognition score.

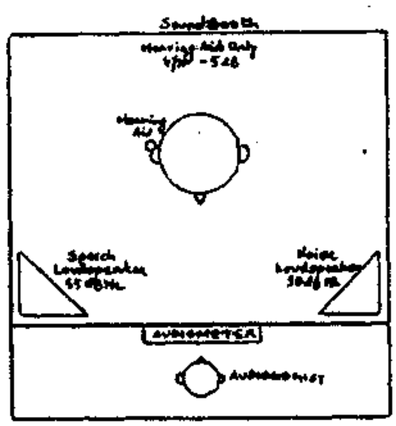


Figure 3-A. Physical assignment in sound booth for speech recognition testing of hearing aid(s) only for comparison purposes to FM system. (Modified from Lewis et al., 1991).

(x)

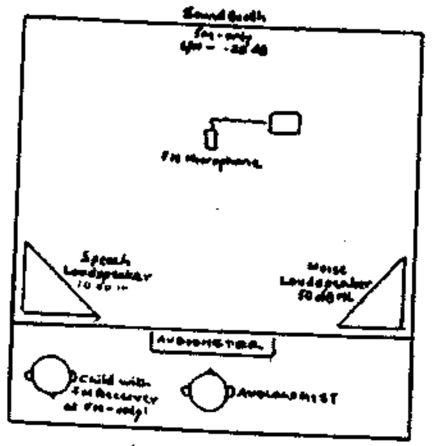
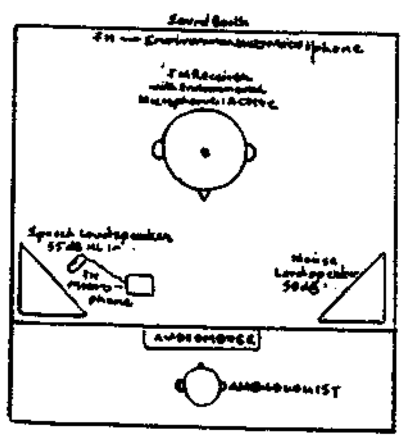


Figure 3-B. Physical arrangement in sound booth for speech recognition testing of FM system set to FM-only for comparison purposes to hearing aid(s) only. (Modified from Lewis et al, 1991).



(xi)

Figure 3-C Physical arrangement in sound booth for speech recognition testing of FM system with environmental microphone(s) active. (see Lewis et al., 1991, for potential difficulties in high-frequency input to the FM microphone using this arrangement).

(xii)

APPENDIX - IV

Hearing Aid test box to assess performance of FM auditory trainer'.

Bees, FM; Freeman, BA; Sinclair, JS. ed. Amplification in Education. Alexander John Bell, Washington.

A. Mode of operation of FM units.

1. FM mode

    a. Teacher microphone unit in box.

    b. Student unit within one meter.

    c. Output of student unit coupled to 2cc coupler.

2. EM mode

    a. Student unit switched to environmental microphone and placed in box.

    b. Measurement procedure similar to that of hearing aid.

B. Preparation for measurement of trainers in FM mode :

1. Rechargeable batteries charged for minimum of 12 hours or per manufacturer's specifications.

2. Check calibration of test box according to manufacturer's specifications.

3. Determine ambient noise level in box :

   a. Place teacher unit in box with microphone oriented according to test box instructions.

   b. Place monitoring microphone of box adjacent to microphone of teacher unit.

   c Close lid, if possible, and record ambient noise level.

4. Measure frequency response of test box chamber :

   a. Teacher microphone unit must remain in test box.

   b. Signal is introduced with level at least 10 dB above overall ambient noise level in box.

   c. Sweep frequency response from lower to upper limits of test equipment.

5. Control settings of teacher and student FM units :

   a. Goal is to approximate ANSI 53.22-1976 procedure.

   b. Settings adjusted to widest frequency range, greatest maximum output, highest gain, and greatest amount of compression.

   c. Repeated measurements should include "use" settings as these may differ substantially from ANSI settings.

d. Important to record settings, signal input levels, and other variables for reliable follow-up measurements at later date.

C Recommended measurements :

1. Internal noise output :

a. Student unit set to full-on gain control.

b. Teacher unit on, with microphone gain control full-on.

c Overall noise level recorded with no input signal present from speaker.

d. Repeat with student unit adjusted to "use" gain control setting.

2. SSPL 90 (saturation output) :

a. Student unit set to full-on gain control.

b. Input signal level at 90 dB SPL.

c. Sweep frequency response.

d. Record high-frequency average SSPL 90 and peak output level and frequency.

3. Gain :

a. For compression instruments, student unit set to full-on gain control. Otherwise, use reference test gain control setting as specified in ANSI-1976.

b. Input signal level must be 10 dB greater than ambient noise level in box. Recommended input at 0 dB SPL.

c. Average high-frequency gain recorded.

d. Repeat measurement with student unit gain control adjusted to "use" setting.

4. Harmonic distortion :

a. Carry out total harmonic distortion procedure according to ANSI-1976 fundamental frequencies and input levels.

b. Procedure regarded as screening method as high ambient noise level may be greater than intensity of harmonics. Low distortion values pass the instrument, while high distortion values only suggest need for further evaluation under more stringent conditions.

5. Battery drain :

a. Gain measurements repeated at end of normal full day use.

b. Determine whether usable gain remains available.

D. Cautions:

1. Limitations of modifications of standard ANSI procedures :

a. Manufacturer's specifications of FM units may differ from results of these tests.

b. Each unit functions as own control.

2. Results must be interpreted with same cautions as apply to hearing aids, particularly to the limitations of the 2cc coupler.

3. Electroacoustic measurements do not substitute for routine troubleshooting, including listening to instrument's output.

APPENDIX - V

Test Protocol for FM system

by Hawkins, D.B.: Mueller M.G.

cited in Mueller, H.G. et al. "Probe Microphone Measurements Hearing Aid selection and assessment".

1. Place ALD microphone in the calibrated or equalized sound field location. If possible, use the substitution method and equalize the field, then locate ALD microphone in the vacant soundfield at the calibrated location. If using modified-comparison method, place the ALD microphone near the regulating microphone.

2. Place probe tube in ear canal 25-30 mm past the tragal notch.

3. Fit receiver of ALD (e.g., earbud or headphones) to the ear.

4. Adjust ALD VCW to desired position.

5. Assuming the ALD will be used with the microphone 6-8 in. from the speaker's mouth, select either a speech-weighted noise at 80 dB SPL or a swept frequency-specific signal at 75 dB SPL.

6. Conduct measurement.

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