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Basic Audiological and Audiometric Concepts of the Amigo FM System



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This document is intended for professionals who fit the Oticon Amigo FM system using test boxes. It gives a brief overview and explanation of the system and its concepts and a general overview of fitting the system using audiometric test boxes.

Overview of FM Systems for Hearing Aids

An FM radio system assists the hearing aid user by providing a clearer signal in unfavorable listening conditions. It consists of at least one transmitter and one receiver. The FM transmitter sends an audio signal picked up by its microphone. This signal is coded (frequency-modulated, FM) onto a carrier radio frequency - a channel much higher than the audio frequency range. The carrier frequency is sent to the receiver, which recovers the original audio signal and transfers it to an attached hearing aid. In this way, the distance between the sound source and the hearing aid user is effectively reduced, thereby providing the listener with a better signal representation of the source than with the hearing aid alone.

The resulting improvement in the signal heard by the hearing aid user is called the **FM advantage**, since the FM signal in the hearing aid is louder than the one from the hearing aid microphone picking up the same sound source, only from much farther away. A 10dB advantage in the FM signal compared to the hearing aid signal can be expected, due to the shorter distance between the FM microphone and the source compared with the distance between the source and the hearing aid microphone [“Guidelines for Fitting and Monitoring FM Systems”, American Speech-Language-Hearing Association, ASHA Desk Reference, 2000].

It is often helpful to use the Signal-to-Noise-Ratio (SNR) definition when considering FM systems. This is a quantitative measure of the amount of noise present in the transmission of the signal. As noise contains no useful information for the listener, it is advantageous that the SNR should be as high as possible. When it is very low, masking of the signal by noise may easily occur until the listener can no longer extract the signal clearly from the noise.

We distinguish between two SNR mechanisms. When there is one sound source to be heard in a certain room, external acoustical noise sources degrade its intelligibility if they are too loud in level compared to the source of interest, as when positioned close to the input microphone. In this situation, the FM advantage is that the signal is given more priority and surrounding noise is naturally suppressed by positioning the microphone correctly.

The second SNR mechanism is inherent to the system and to the FM transmission. As in every electronic system, some internal noise is generated by the components. Also, the transmission degrades with distance, and extra electronic noise is accumulated with increasing separation between the receiver and transmitter. When this noise becomes too loud compared to the signal, a loss in intelligibility occurs. Generally, in normal working conditions and average sized rooms, this noise is lower than the background acoustical noise and therefore goes unnoticed by the hearing aid user.

The Amigo FM System

The Amigo T20 and T21 transmitters operate in a selection of FM channels according to the permitted frequencies of the country of residence. These transmitters are supplied with an omni-directional microphone, but more accessory microphones are available, such as directional and boom microphones.

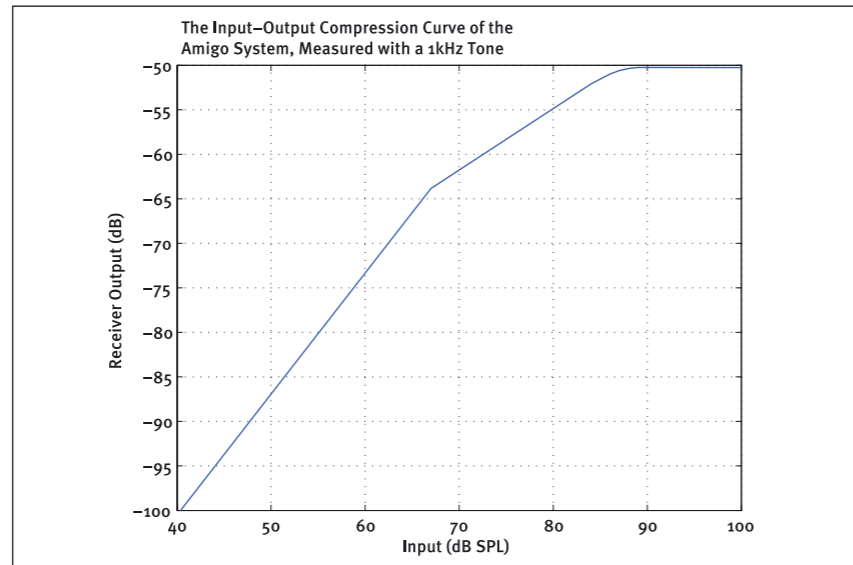
The Amigo R1 and R2 receivers are connected to the hearing aid or cochlear implant through an FM Adaptor using the standard Euro-pin connector. The R7 receiver is dedicated to the Sumo hearing aid family and connects directly to them, without an FM adaptor.

Both transmitter and receiver can be easily programmed by the transmitter. When fitting the Amigo system, it is necessary to choose the same channel on both transmitter and receiver and to adjust the receiver gain.

The operational range of the FM system varies between rooms, but up to 30 meters can be expected if there is no interference of any kind. The farther apart the transmitter and receiver are (beyond a certain “full quieting” distance), the noisier the transmission will become. When the noise in the receiver exceeds a certain level (10dB SNR), the Amigo receiver will cut (squell) the transmission altogether, in order to maintain a decent and intelligible sound quality.

The system audio bandwidth is 7.5 kHz, which covers speech signals and has a flat response.

The transmitter response is not completely linear, as it compresses the input signals by 1.45:1 between 67 and 87 dB SPL input level (67dB SPL kneepoint). This is referred to as Dynamic Range Optimization, as the compressor brings the most typical input levels closer to an average speech level of 77dB SPL. Higher level inputs are hard limited.



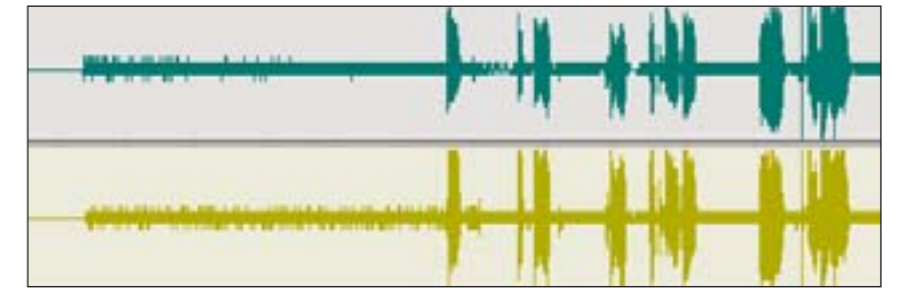
The input/output characteristics of the Amigo systems, with acoustical input given in dB SPL and the corresponding electrical output that goes to the hearing aid.

Below the input kneepoint of 67 dB SPL, the Amigo transmitter attenuates incoming signals, using an expansion ratio of 0.7:1. This Amigo feature is called Auto Mute (similar to Soft Squelch in hearing aids) and it effectively reduces the amount of noise transmitted into the receiver in quiet ambiance. The slow release time of the compressor ensures a smooth transition when the speech ceases but the fast attack time ensures no loss of information when the speech resumes.

The transmitter has a feature called “Advanced DSP”. Enabled by default, this feature controls the “Static Noise Avoidance” of the Amigo. It minimizes stationary (unmodulated) noise coming from fans, computers, projectors, etc. Modulated noise such as speech and music are left unaffected.



Amigo’s output from a white noise input with Noise Management on (Top) and off. The attack time from the detection of the unmodulated noise until reaching a steady state is about 5.5s.



Impact of the static noise management circuit. In this example, a female speaker is talking at +12 dB SNR with a static noise signal in the background (white noise). In the top panel the noise management is turned on, while in the bottom it is turned off. This shows that, in situations where there is no speech, less noise is delivered to the child’s hearing aid/cochlear implant. Importantly, speech information is not removed.

Amigo employs special emphasis filters that improve the quality of the transmitted FM signal. A complete Amigo system would have a flat response. However, in cases where the Amigo system is mixed with FM equipment of another brand, the emphasis filters should be disabled to maintain the signal transparency of the system.

Hearing Aid Non-linearity

Hearing aids can be classified into linear and non-linear aids. Linear instruments amplify all inputs equally, regardless of the input level. But non-linear aids have variable gain for different input levels. Therefore, non-linear aids would generally show a smaller difference in the output than in input (compression). This difference should be taken into account when performing the fitting.

Most modern hearing aids offer advanced features that, are non-linear by nature. These include:

1. Noise reduction
2. Feedback cancellation
3. Fixed directionality.

These features should be turned off prior to the FM fitting.

Fitting with Test Boxes

Measurement and fitting of the FM systems in test boxes are a simple means to get repeatable and controlled data, although they do not always correspond to realistic situations for a variety of reasons. Some of these may include synthetic signals used in tests; the differences between the assumed speech sound pressure level and the actual speaker's level; the differences in microphone amplification in near-field and far-field; and complicated non-linear behaviour of the FM system and hearing aid.

It must be emphasized that it is very important to make an additional subjective test on the hearing aid user in order to validate that the system is performing satisfactorily.

Before fitting an FM system, make sure that the hearing aid is fitted correctly.

Calibration

The test box must be calibrated properly for box sound pressure level measurements using the instrument-recommended calibration scheme.

Hearing Aid Linear Behaviour Detection (optional)

If it is unknown whether the hearing aid employs non-linearity, it must be tested beforehand. Some aids, such as Sumo DM, can be programmed either way and therefore it can be useful to test them regardless. In order to confirm whether an instrument is linear or non-linear, response curves at three different input levels (50dB, 65dB and 80dB SPL) should be measured. If the difference between the curves is smaller than the established 15dB difference in the input levels, then the instrument is indeed non linear.

FM Fitting

The first step in an FM fitting is to measure the hearing aid response curve at 65dB SPL through the coupler microphone. Then, take the instrument out of the box and put it to one side, still connected to the coupler. Attach the receiver to it and turn it on. Then, place the transmitter microphone in the same reference position in the box repeat and the measurement at 65dB SPL. Compare the two measurements to see whether the levels are similar. If the FM output is different than the instrument output, adjust the receiver gain accordingly. Repeat the process until the two curves more or less overlap. Finally measure the FM system again at 80dB SPL to ensure an FM advantage of up to 10dB. Note that the expected 10dB advantage can be lower when measured in a test box, as a result of the transmitter compression.

Signal Types in Different Test Boxes

Different test boxes have various test signals, which often get different names. More complex speech-like signals are always preferable in order to obtain a more realistic result. Traditional white noise, pink noise and pure tone sweeps should be avoided wherever possible, as they may activate some of the non-linear features in the aids or transmitter, if these were not disabled beforehand.