Fitting hearing aids to a patient with Meniere's disease can present a number of challenges to the audiologist. This article summarises some of the strategies and technologies that could be implemented by the audiologist to address these unique challenges and provide a greater opportunity for a successful hearing aid fit. These include:

1. the advantages offered by digital signal processing;
2. using directional microphones and assistive listening devices to improve speech recognition in noise;
3. using wireless CROS and BICROS hearing aids;
4. using multiple programs for patients with fluctuating hearing loss and
5. counselling patients on the realistic expectations from amplification in noisy listening situations and for those with poor speech recognition.

The broad aim in fitting a hearing aid is to amplify speech to fit within the listeners' dynamic range of hearing. The most common hearing problems reported by people with Meniere's related sensorineural hearing loss are: Fluctuating low frequency hearing loss; Progressive development of hearing loss; Distorted Pitch Perception; Variable Perception of Growth of Loudness; Unilateral or Bilateral Hearing Loss; and Tinnitus. The presence of any one of these characteristics can create obstacles for a successful hearing aid fit. The presence of most if not all of these characteristics in a single patient can readily challenge the skills of even the most experienced audiologist. In addition to the audiometric challenges, there are the added psychological problems associated with feeling ill due to the nausea secondary to vertiginous attacks and the anxiety associated with the unpredictable nature of the course of these attacks. Developments in digital hearing aid technology, by expanding the types of signal processing that can be incorporated into a hearing aid, have resulted in hearing aids being produced which help resolve many of these difficulties.

Signal Processing Characteristics of DSP hearing Aids
- Dynamic Range Of Hearing
The dynamic range of hearing can be defined as the intensity range between hearing threshold level and loudness discomfort level. Digital processing hearing aids selectively provide sufficient gain for soft speech sounds, whilst at the same time restricting the growth in loudness of louder environmental sounds.

It is often assumed that as hearing sensitivity decreases that tolerance levels for loud sound will increase proportionally. This is not the case. We cannot estimate with any degree of accuracy
probable loudness discomfort levels, for any one individual, based on their hearing threshold data alone. Nor can we assume that someone with a moderate hearing loss will have a broader dynamic range than someone with a severe hearing loss. The dynamic range available, or usable range of hearing, will often vary at each frequency.

In general people with Meniere’s disease have a narrower dynamic range in those frequencies where the hearing injury is most severe. To optimise speech understanding it is desirable to place the speech peaks at all frequencies from 200 - 5000Hz, at least 30dB above the hearing threshold level (ANSI, 1969). As the level of a speech signal increases, the perception of loudness increases rapidly from threshold to discomfort level. Digital processing hearing aids are able to selectively provide sufficient gain for soft speech sounds, whilst at the same time restricting the growth in loudness of louder environmental sounds.

- **Frequency Resolution**
  A major limitation in achieving optimal speech discrimination is the amount of spectral information that can be extracted by the individual from the limited speech signal that they are receiving. Frequency selectivity or frequency resolution is our ability to hear or separate the different frequency components in a complex sound. It is one of the most basic aspects of human hearing. Frequency selectivity is commonly impaired in Meniere’s disease and can lead to considerable difficulty in understanding speech, particularly in noisy situations. Frequency selectivity is important in determining whether one sound will mask another. The upward spread of masking effect, where the more intense low frequency sounds overwhelm the relatively softer high frequency speech sounds is the rationale behind the high frequency emphasis of most hearing aids. Without frequency selectivity we would have great difficulty in hearing speech in moderately noisy situations.

  Frequency selectivity is important in the perception of loudness, timbre and pitch. Digital hearing instruments with multi-channel amplifiers have the capacity to selectively amplify specific regions of the speech signal. In this way the low frequency and high frequency areas may receive a completely different amplification strategy.

- **Temporal resolution**
  Temporal resolution is our ability to follow changes in the time pattern of sounds. Decline in temporal resolution ability is also common in Meniere’s disease. Like frequency resolution, temporal resolution is essential for the understanding of speech since without it we cannot detect or analyse the rapid changes that are crucial in distinguishing different speech sounds. Poor temporal resolution ability can cause speech to sound blurred or indistinct, as if people are mumbling all the time. Sophisticated noise reduction algorithms available in digital signal processing hearing aids assists listening in these difficult environments. The frequency resolution and temporal resolution reductions typically found in clients with Meniere’s disease related hearing losses are probably the major source of the difficulties experienced in understanding speech, particularly in noise.

**Directional Microphones**

People with Meniere’s disease often have great difficulty with spatial perception due to their hearing loss being greater in one ear than the other, for example when trying to select a single sound source in multi-talker background noise. Research has shown that the most effective way of improving the hearing of speech in background noise is to select a hearing aid with at least two
microphones. One microphone picks up sound all around (omnidirectional hearing) and is used in a quiet environment, while a second microphone picks up sound just in front of you (directional hearing) and may have the capacity to zoom towards a dominant voice. Directional microphones have been shown to offer a partial solution to difficulty hearing in background noise by improving the signal to noise ratio at the speech reception threshold. Studies comparing directional to non-directional (omni) aids have shown that in noisy situations directional hearing aids offer superior intelligibility to the wearer, even in reverberant environments. Some models offer adaptive microphone directionality, with the hearing aid tracking the location of the noise and automatically limiting amplification from that direction. Digital hearing aids incorporating directional microphones have been available since the early 1990's.

**Binaural Hearing**
There are many binaural psychoacoustic phenomena that are important for speech perception in background noise. Some of these are:

- Binaural loudness summation: listening through two ear leads to an increase in sensitivity of up to 6 dB.
- Improved localization: the ability to spatially separate speech sounds can be reduced if the interaural sensitivity differences are as little as 10 dB, either due to pathology or artificially induced.

All real work listening tasks are performed in a reverberant environment. Binaural hearing enables speech intelligibility to be significantly enhanced when either the speech signal or the noise is out of phrase. Binaural hearing provides superior speech discrimination over monaural hearing in reverberant environments.

**However sometimes an ear is unaidable**
Unfortunately sometimes an ear can be so severely damaged that there is little or no benefit to be obtained by wearing a hearing aid in that ear. In ears where there is no measurable hearing; extremely poor speech understanding; unmanageable loudness tolerance issues; medical conditions prohibiting ear mould use; and ear canal malformations

**Contralateral Routing Of Signal (CROS) Hearing Aid Systems**
One approach is to use a hearing aid system where the signal reaching the unaidable ear is transferred wirelessly to a hearing aid on the good ear. In such a system you have an active microphone on unaidable ear (Transmitter), that is sending a signal to a hearing aid, worn on the good ear, in which the microphone is turned off (Receiver). Such a system is used when there is essentially normal hearing to mild hearing loss in the better ear and the demands placed on listening are high because of lifestyle or occupation.
Bilateral Routing of Signal (BICROS)
In some cases there is also a hearing loss in the better ear that also requires amplification. In this situation a BICROS hearing aid system is utilised where an active microphone is placed on the unaidable ear (Transmitter) and an active microphone is on an aidable ear (Hearing Aid). In both these hearing aid systems sound detection from the unaidable side is enhanced, but these systems cannot restore the binaural hearing cues that enable localisation of sound or three dimensional separations of competing sounds.

Automatic Signal Processing
Every manufacturer of hearing aids has technology that "intelligently" adapts to the presence of background noise, thereby improving the hearing aid users' ability to hear under adverse listening conditions. Automatic signal processing systems (ASP) are continuously variable low frequency filter systems that provide increasing suppression (more high frequency emphasis) with increasing levels of noise. This essentially makes them into a broadband hearing aid in quiet and a high frequency emphasis hearing aid in low frequency noise. In a digital hearing aid a microprocessor replaces the hardware used to process the signal i.e. the filtering and compression systems. Digital hearing aid systems allow far more precision in the specification of hearing aid response characteristics resulting in increased fidelity and comfort with the sound quality.

For many people with hearing loss the hearing impairment is usually worse in high frequencies. Many important sounds contain mostly high frequencies e.g.: Birdsong, and in speech: unvoiced fricatives /s/ and /sh/. Some people with a severe hearing impairment in the high frequencies cannot detect or easily discriminate high frequency cues. There are now some digital signal processing strategies that can transfer key discrimination cues to a lower frequency to improve the signal audibility. Numerous different frequency-lowering schemes have been developed and evaluated. Some of these strategies have been shown to improve speech understanding for certain hearing-aid users, and have been incorporated into newer DSP hearing aids such as Widex Audibility extender and the Phonak Sound Recover systems.

Advantages of Programmability
In modern digital hearing aids the frequency response, the maximum power and the compression parameters are specified by the software and are not limited by the hardware characteristics. This means that if the persons hearing changes, the hearing aid can be reprogrammed to suit the current hearing levels, without incurring the cost of purchasing a new hearing aid.

Digital hearing aids can also offer multiple listening programs for various listening environments (eg conversation in quiet, conversation in noise, telephone, telecoil or induction pick-up, music, FM listening), which in most cases can be separately adjusted and fine-tuned. Some models automatically select the appropriate listening program depending on the noise level and types of sounds in the environment, automatically giving you the greatest clarity or comfort in different situations.
The advantage of multiple listening programs is that you are more likely to get improved speech understanding in a greater variety of circumstances. Hearing levels and hearing acuity can fluctuate significantly with the active phases of Meniere’s disease. Multiple alternative hearing aid programs can be set up for the “good” and the “bad” days, leading to an increased sense of being able to control one of the more frustrating aspects of Meniere’s disease.

Software driven digital hearing aids can be adjusted to suit any pattern of hearing loss and a whole range of signal processing capabilities can be built into them. As well the calibration, the hearing testing procedure and the hearing aid fitting can be performed using computer-controlled systems. Digital hearing aids contain few analogue parts and the characteristics of the hearing aid are stored in software memory so hearing aid performance should remain stable over time, producing fewer problems, greater reliability and therefore greater user satisfaction.

**Auditory Adaptation**

Modern digital hearing aids due to their speed of processing and ability to expand soft sounds greatly increase the complexity of the sounds you are hearing. Because hearing loss is likely to have developed gradually over time, your concept of what is “normal” hearing has slowly changed. When hearing aids are fitted for the first time and sounds are boosted to the level they should be heard, your concept of “normal” hearing will need to be adjusted. You will hear sounds that you have not heard for a long, long time. Some of these will be pleasant sounds, like the songs of the birds or high-pitched voices of children. Other less pleasant sounds need to be heard for our safety and/or general knowledge of what is happening around us. These are sounds like the refrigerator or air conditioning units humming and buzzing, the sound of our footsteps, or a "knock" in the sound of the car engine. Some environmental sounds will seem unnaturally prominent or noticeable for the first few weeks. It takes time for the brain to re-learn all these sounds. Be patient! Research has shown that this adaptation or adjustment period may last a few months. For this process of adaptation to occur, you are best advised to wear your hearing aids for most of the day. If you use your hearing aids on an occasional basis you will continue to feel awkward with them, and will not adapt fully to them. Your aim is to have what you hear through the hearing aids become “normal”.

**Competent Dispensing**

Digital technology offers the potential to be able to manipulate the spectral and temporal cues of hearing. As the technology utilised in hearing aids increases in its sophistication, the skills required by the clinician fitting this equipment increases enormously. Regulation of the minimum level of training and experience required by clinicians dispensing this technology is essential to protect the consumer. Past experience has indicated that the consumer alone does not have a sophisticated enough level of understanding of the technology to protect them from inappropriate application of the technology and overcharging. University trained audiologists are the only group with the diverse range of skills and training to be able to adequately apply this technology.

Hearing aids, now and in the foreseeable future, cannot solve all hearing problems they are an aid, not a solution. We cannot through technology totally overcome the perceptual distortions produced by sensorineural hearing loss. Communication is a complex process. Fitting of an appropriate hearing aid system is but one part of an effective aural rehabilitation program.