Effect of Varying the Amplitude and Frequency Modulation Phase Relationship on Steady State Evoked Potentials

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Introduction

As Steady State Evoked Potentials are used increasingly to determine threhsold, the aim of this study was to optimise the stimulus used. This was investigated by recording SSEPs to AM tones, FM tones and MM tones with a range of relative AM/FM phase settings. These recordings were made in normal hearing adults to air-conducted and bone-conducted stimuli and neonates to air-conducted stimuli.

A sinewave was fitted to some of these results to predict a stimulus phase setting that would give the largest response

MATLAB was used to create a model which described the relationship between the stimulus and electrical response

Experimental Methods

Subjects

Adult Air-Conduction

11 Female, 9 Male Normal Hearing Adults

Adult Bone-Conduction

10 Female, 10 Male Normal Hearing Adults

Neonatal Air-Conduction

10 Female, 10 Male Normal Hearing Neonates <3 months old (as tested with ABR)

Equipment

Recordings were made with the MASTER system and a CED Amplifier and Kamplex KC 4 Audiometer

Stimuli

Modulation Rate between 78Hz and 92Hz

Carrier Frequencies of 500Hz, 1kHz, 2kHz and 4kHz presented simultaneously, monaurally

100% Amplitude Modulation

20% Frequency Modulation (+/-10%)

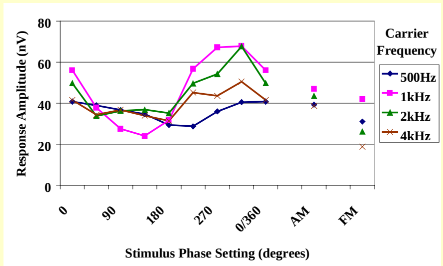
Mixed Modulated Stimuli with relative AM/FM phase setting 45° apart

Bone-Conduction Recordings

- There is a risk that the induced current from the stimulus electromagnetic field from the transducer may be picked up directly by the electrodes and could be mistaken as an auditory response. The electro-magnetic field is higher for a particular stimulus level when using a bone vibrator than for an earphone. To investigate this, a dummy patient, made up of a set of resistors was used to assess the level of the stimulus artefact. A large response was recorded at the modulation frequency similar to a true response. A range of possible solutions were explored to reduce the artefact. The solution which appears to offer the greatest reduction of artefact is to shield the bone conductor in a grounded mu-metal can, and ground the cable to the bone conductor. During the experiments, control recordings were included to ensure that measurements made were not artefact.

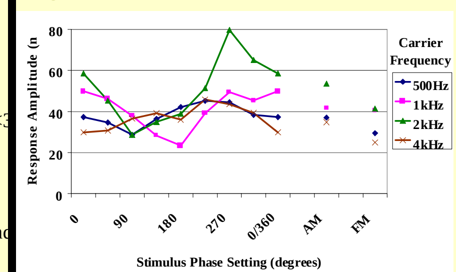
Figure 1
Bone-Vibrator
in a Mu-metal Can

Figure 2; Adult Air-Conduction Results



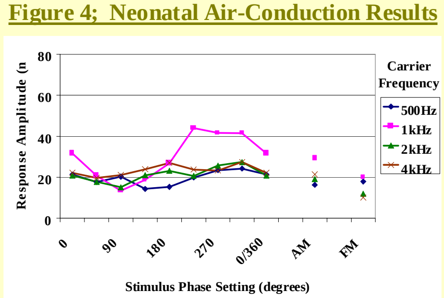
- Changes in amplitude were statistically significant for carrier frequencies of 1kHz, 2kHz and 4kHz but not 500Hz
- As indicated by a sinewave fitting to this data, the phase setting which would evoke the largest responses are 300° for 1kHz, 295° for 2kHz and 280° for 4kHz.
- No significant effects of gender on response amplitude were found

Figure 3; Adult Bone-Conduction Results



- As with the air-conduction results, changes in amplitude were statistically significant for carrier frequencies of 1kHz, 2kHz and 4kHz but not 500Hz
- As indicated by a sinewave fitting to this data, the phase setting which would evoke the largest responses are 275° for 1kHz, 290° for 2kHz and 240° for 4kHz.
- No significant differences between air- and bone-conducted response amplitudes were found

Figure 4; Neonatal Air-Conduction Results



- Changes in amplitude were statistically significant for carrier frequencies of 500Hz, 1kHz, 2kHz and 4kHz however at 500Hz, 2kHz and 4kHz the effect appeared to be small
- As indicated by a sinewave fitting to this data, the phase setting which would evoke the largest response at 1kHz was are 275°
- The response amplitudes were significantly smaller in neonates than adults
- As in the adult group no significant effects of gender on response amplitude were found

Model

The model was based on the effect that the travelling wave has on the timing of the neural stimulation. As the different regions of the cochlea are sensitive to different frequencies, when the sound entering the ear is frequency modulated it will move around the cochlea depending on the frequencies it contains. As the sound travels on the basilar membrane it takes different lengths of time to reach the region that it will stimulate. Therefore a sound will stimulate the auditory nerve with a different time shift depending on the frequencies it contains. The time shift used was defined by Eggermont (1979). The model is described by the flow chart in Figure 5.

Figure 5; Model Flow Chart

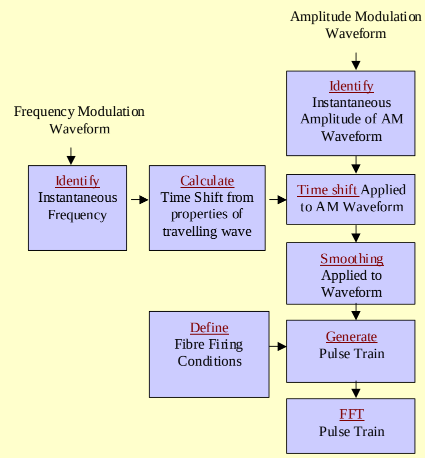
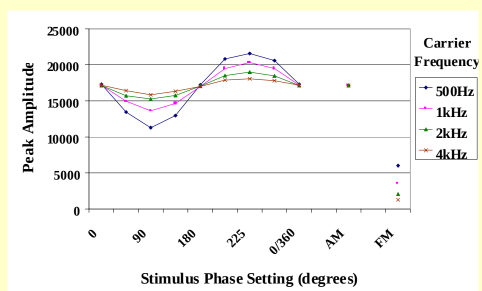


Figure 6; Model Results



- Similar changes in output amplitude between the experimental data and the model were observed for 1kHz, 2kHz and 4kHz
- Differences included the large effect of stimulus phase in the model output for 500Hz which was not observed in the experimental results
- Improvements could include including a tuning curve function and adjusted to firing conditions

References

John M.S. Dimitrijevic A. van Roon P. Picton T. (2001), **Multiple Auditory Steady State Responses to AM and FM Stimuli** Audiological Neuro-otoloy 6 12-27

- Dimitrijevic A. John M.S. van Roon P. Picton T.W. (2002)

Human Auditory Steady State Responses to Tones Independantly Modulated in both Frequency and Amplitude JAAA 13 205-224

- Eggermont J.J. (1979) **Narrow-Band Action Potential Latencies in Normal and Recruiting Human Ears** JASA 65 463-470