Two Component Acoustic Reflex Measures
as a function of
Probe Frequency

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CONTENTS

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ABSTRACT

Previous research on the acoustic reflex using immittance measurements has been limited to narrow probe frequency and/or stimulus intensity ranges, leaving some unanswered questions concerning the pattern of susceptance and conductance reflex recordings in normal ears. The present study was an investigation of the effect of probe frequency, stimulus intensity, stimulus frequency and middle ear resonance on the direction, magnitude and morphology of susceptance and conductance reflex patterns measured at the probe tip. Part one of the study was an exploratory investigation to establish the magnitude, direction and morphology of measured susceptance and conductance reflex patterns, measured ipsilaterally at three probe frequencies (226, 678 and 1000 Hz) for three stimulus frequencies (0.5, 1 and 2 kHz) across a wide intensity range (66 - 110 dB HL). The results, analysed for 19 ears, suggested that direction, magnitude and morphology of these reflexes may be closely related to where probe frequency lies in relation to the resonant frequency of an individual. The results appeared to be consistent with a constant resistance, stiffness change model. This relationship was investigated further in the second part of the study. Three aspects were investigated: the classification of reflex patterns in relation to baseline transmission characteristics at a 1000 Hz probe frequency and associated phasor plots; the direction of susceptance and conductance reflexes at each individual's resonant frequency; and the effect of adding stiffness to the external auditory meatus on diphasic reflex patterns. The results suggested that the direction of susceptance and conductance reflexes was determined by baseline transmission properties and the reflex growth patterns indicated that the effect of the reflex was usually an increase in stiffness. Diphasic reflexes at the 1000 Hz probe frequency became monophasic when stiffness was added to the baseline condition. Further research is needed to clarify issues related to the effect of the reflex on mass dominated systems.

CHAPTER 1
INTRODUCTION

The effect of the acoustic reflex on the transmission of sound through the middle ear is best determined using indirect immittance measures (Hung and Dallos, 1972). Although extensive research has been conducted into the effects of the acoustic reflex on the input impedance and admittance of the middle ear (for example Møller, 1961; Zwislocki, 1962; Feldman and Williams, 1976, Lutman and Martin, 1979; Bennett and Weatherby, 1979) there remain several unanswered questions in relation to the effect of probe frequency, stimulus intensity and stimulus frequency on the magnitude, direction and morphology of reflex patterns. This chapter aims to provide background information as to the effect of the acoustic reflex measured using immittance methods and provide the rationale for the further investigation of acoustic reflex patterns.

The middle ear functions as a complex transmission system which matches the impedance of the inner ear to that of air (Møller, 1983). Electroacoustic models of middle ear function, such as those developed by Møller (1961) and Zwislocki (1962), indicate that the middle ear consists of various functional units which have anatomical correlates. These early models divided the units into representations of the middle ear cavities, tympanic membrane, tympanic membrane-malleus-incus, incudostapedial joint and stapes-cochlea-round window complexes. A later model developed by Lutman and Martin (1979) has built on these early models and added a further unit to represent the acoustic reflex.

Examining the transmission characteristics of each of the functional units in the middle ear directly is not possible in living human subjects, as this requires comparing input and output impedance of the middle ear, and there are no noninvasive procedures which allow for this at present (Gundersen and Hogmoen, 1976). For this reason direct investigations of middle ear transmission characteristics have been restricted to temporal bone studies and animal studies (for example Funnell and Laszlo, 1982; Brenkman, Grote and Rutten, 1987). However, it is unclear to what extent findings from temporal bone studies can be extended to living systems as tissue change occurs after death (Møller, 1961; Lokberg, Hogmoen and Gundersen, 1980). Additionally, temporal bone studies can only consider the transmission characteristics without the acoustic reflex as activation of the reflex requires neural activity in the brainstem and cranial nerves (Gundersen and Hogmoen, 1976). Animal studies also have limited application in terms of determining transmission characteristics with the acoustic reflex as the acoustic reflex in animals is known to represent the action of both the tensor tympani and stapedius muscles, whereas in man only the stapedius muscle is considered to contract (Djupesland, 1980).

It is of interest therefore to examine the effect of the acoustic reflex on the transmission characteristics of living human subjects. Indirect immittance measurements made at the entrance to the external auditory meatus and corrected to the plane of the tympanic membrane provide a reasonable approximation of middle ear properties (Hung and Dallos, 1972; Hirsch, 1983). Immittance recordings are usually made in admittance, rather than impedance due to the linear relationship between recordings at the entrance to the external auditory meatus and tympanic membrane for admittance components (Margolis, 1981; Silman and Silverman, 1991). Whereas overall admittance is the inverse of impedance, a more complex relationship exists between the components of admittance and impedance. Measured susceptance and conductance values, corrected to the plane of the tympanic membrane, can be converted to reactance and resistance values using the formulae presented in Table 1. While admittance is used for ease of measurement, impedance quantities are often used for the explanation of immittance patterns (Van Camp and Creten, 1976).

Table 1: **Equations used to convert impedance components to admittance components, taken from Margolis and Popelka (1977)**

$jB = -jX / (X^2 + R^2)$	$G = R / (X^2 + R^2)$	B = Susceptance	G = Conductance
$jX = -jB / (B^2 + G^2)$	$R = G / (B^2 + G^2)$	X = Reactance	R = Resistance

Reactance and resistance interact in systematic and predictable ways across frequency (Vanhuyse, Creten and Van Camp, 1975). This reflects the different axes of ossicular rotation at low and high frequencies and a loss of energy at the incudostapedial joint when high frequency sounds are transmitted through the middle ear system (Gundersen and Hogmoen, 1976; Brenkman et al, 1987). In the normal adult ear, reactance varies across frequency, assuming negative values (stiffness domination) at low frequencies and positive values (mass domination) at higher frequencies (Funasaka, Funai and Kumakawa, 1984), whereas resistance does not vary significantly as a function of frequency (Creten, Vanpeperstraete and Van Camp, 1978; Wiley and Bock, 1985). Resonance represents the frequencies at which the reactance is at a minimum, and resistance forms the major component of impedance (Van Camp and Vogeleer, 1986). Resonance in the human living system is in the region of 1000 Hz (Colletti, 1977). Natural frequency is differentiated from resonant frequency in terms of the type of measurement made (Lutman, 1993). However, natural frequency approximates the resonance of the system (Lutman, 1984). Most researchers use the term resonance, or resonant frequency, when referring to this phenomenon (for example, Van Camp and Vogeleer, 1986; Holte, Margolis and Cavanaugh, 1991; Hanks and Rose, 1993). This same convention will be followed in the present study.

The recording of static immittance components at the lateral surface of the tympanic membrane using immittance methods does not differentiate between functional units within the middle ear, but rather represents stiffness, mass and friction within the middle ear as a whole (Lutman, 1984). Transmission characteristics (or modes of vibration) which vary naturally as a function of frequency in terms of becoming less stiffness dominated with increases in frequency, can be changed by either introducing pressure variations in the external auditory meatus, recorded using tympanometry, (Berlin and Cullen, 1980); activating the acoustic reflex, recorded as change in immittance due to the reflex (Brenkman et al, 1987); or by the presence of pathology (Elpern, Greisen and Andersen, 1965). Dynamic measures of transmission characteristics, whereby probe frequency, pressure in the external auditory meatus or intensity of a reflex eliciting stimulus are varied, have allowed for more specific information being obtained about the acoustic properties of the tympanic membrane and ossicular chain, each of which functions as a separate subsystem of the middle ear (Lutman, McKenzie and Swan, 1984; Wada, Kobayashi, Suetaki and Tachizaki, 1989; Wada and Kobayashi, 1990).

The introduction of pressure in the external auditory meatus occurs as a result of experimental manipulation. The tympanic membrane is effectively stiffened so that the introduction of sound pressure does not result in the required tympanic membrane vibration for optimal sound transmission (Møller, 1983; Silman and Silverman, 1991). Because pressure variations result in stiffening of the tympanic membrane, it is the reactance quantity which changes as air pressure is varied (Creten et al, 1978). The reactance value, as mentioned, is dependent on the frequency of the sound being transmitted through the middle ear (Margolis, Van Camp, Wilson and Creten, 1985). For any frequency however, the introduction of extreme pressure variations will result in more negative reactance values, as compared to conditions where there is no pressure differential across the tympanic membrane (Vanhuyse et al, 1975). Reactance values therefore shift as pressure is varied, but the absolute value is dependant on the frequency being transmitted. Resistance does not change significantly over the frequency range and pressure variation range usually incorporated in studies of middle ear transmission (Van Camp, Vanhuyse, Creten and Vanpeperstraete, 1978). However, the relative importance of the resistance factor as a component of overall impedance varies across frequency and pressure variations because changes in the reactance lead to relatively more or less contribution to impedance from resistance (Holte et al, 1991). Thus during tympanometry, probe frequency and pressure interact to determine the relationship between resistance and reactance, as indicators of middle ear transmission characteristics (Margolis and Popelka, 1977; Wada and Kobayashi, 1990).

Transmission characteristics of the middle ear system can also be altered through the activation of the acoustic reflex. The acoustic reflex is a natural response of the auditory system to high intensity auditory stimulation, being observed at intensity levels 70 to 80 dB above behavioural thresholds (Dallos, 1964). The reflex threshold is the lowest intensity of an acoustic stimulus at which impedance or admittance change can be recorded in response to acoustic stimulation (Wiley and Block, 1979). The reflex has been shown to be a stable measure within individuals, varying only slightly as a course of normal physiological fluctuations (Lutman and Martin, 1976; Laws and Moon, 1986). Increases in intensity levels of reflex eliciting stimuli yield increases in the amount of impedance or admittance change (Wilson and McBride, 1978). This increase in the amount of admittance change related to the intensity of the eliciting signal is termed reflex growth (Sprague, Wiley and Block, 1981). Saturation is reached when further increases in intensity of the reflex eliciting stimulus are not accompanied by increasingly large immittance changes (Wilson and McBride, 1978). Saturation is considered to occur at up to 40 dB above reflex threshold (Lutman and Martin, 1977).

Researchers are all in agreement that for low probe frequencies (those below the natural frequency of the middle ear) the major effect of the reflex is an increase in stiffness. However, there are differences in opinion expressed as to the effect of the reflex on resistance. Some researchers, such as Lutman and Martin (1979); Lutman (1984) and Lutman et al (1984) promote a constant resistance, stiffness change model. While still acknowledging that some resistance decrease may occur during strong contractions of the stapedius muscle, they stress that regardless of probe frequency or stimulus intensity, the overall effect of the reflex is an increase in stiffness. Evidence to support this stand in the form of phasor diagrams, consistent with a constant resistance, stiffness change model, have been presented only for low probe frequencies (220 and 660 Hz). Other researchers (for example Feldman and Williams, 1976; Creten et al, 1976; Bennett and Weatherby, 1979) have attempted to either explain the reflex pattern obtained for susceptance and conductance on the basis of reactance and resistance reflex patterns, or to measure the impedance components directly. Where data has been presented in the form of reactance and resistance reflexes, there has been an emphasis placed on the contribution of resistance decreases to either the direction or morphology of susceptance and conductance reflex patterns, particularly for probe higher probe frequencies (660 Hz and above). It is unclear from the previous studies whether these differences in opinion reflect different methodological considerations, or whether different explanations for the same phenomenon are being offered. It may be that the contribution of resistance to impedance decreases, relatively speaking, as negative reactance increases. This may be reported by some researchers as an increase in stiffness and by others as both an increase in stiffness and a decrease in resistance. There is however, an accepted explanation for the decrease in resistance as resulting from the decoupling of the incudo-stapedial joint when the reflex is activated (for example Feldman and Williams, 1976; Lutman and Martin, 1979), and this phenomenon cannot therefore be ignored. Direct comparisons of available findings is not possible given many different , and sometimes unexplained methodological issues (Lutman, 1993).

During acoustic reflex measurements the value of admittance components with the stapedius muscle at rest are compared to the values of these components with the acoustic reflex activated (Wiley and Block, 1979). The equipment used in many clinical investigations of the acoustic reflex baselines the admittance value in the resting state to zero, and then represents the admittance change associated with the activation of the reflex as an increase or decrease relative to zero. Changes in middle ear admittance or impedance (or components thereof) caused by the reflex have the properties of magnitude, direction and shape. Magnitude refers to the amount of change which occurs in absolute value. Direction refers to whether there is an increase or decrease as compared to baseline values. Shape or morphology refers to whether the reflex induced change remains in the same direction over time (monophasic changes) or whether the direction changes over time (diphasic changes). The available literature presented below suggests that these properties of reflex recordings (magnitude, direction and morphology) are determined by underlying transmission characteristics related to probe frequency, as well as by stimulus properties (frequency and intensity).

The direction and magnitude of reflex patterns for the components of admittance have been investigated extensively using probe frequencies of 220 and 660 Hz. Similar findings are reported across studies using various methodologies for these two probe frequencies. The findings reported are that overall admittance decreases when the reflex is recorded at probe frequencies close to 220 Hz (Møller, 1961). The decrease in admittance reflects decreases in both susceptance and conductance (Feldman and Williams, 1976; Lutman and Martin,1977). Larger overall admittance change has been reported for probe frequencies in the region of 660 Hz than for those close to 220 Hz (Bennett and Weatherby, 1979). This change in overall admittance reflects susceptance increases and conductance decreases (Lutman et al, 1984). The relative magnitude of susceptance and conductance reflexes also varies as a function of probe frequency. At 220 Hz susceptance reflexes are larger than conductance reflexes, whereas at 660 Hz conductance reflexes are larger than susceptance reflexes (Wilson and McBride, 1978). Feldman and Williams (1976) stress the importance of examining both the components of either admittance or impedance at higher probe frequencies because although the effect of the reflex is small on overall impedance (or large on admittance), there are identifiable and different effects on each of the components. Feldman and Williams (1976) and Bennett and Weatherby (1979) have shown that the decreases in susceptance and conductance at low probe frequencies (220 Hz) reflect relatively large increases in negative reactance and small increases in resistance. The increases in susceptance and decreases in conductance at slightly higher probe frequencies (660 Hz) reflect large increases in negative reactance and decreases in resistance. The proponents of the constant resistance, stiffness change model present data which is in close agreement with these researchers. Lutman and Martin (1979) agree that the major effect of the reflex is an increase in stiffness (negative reactance) as shown by phasor diagrams with susceptance represented in the Y axis and conductance on the X axis, and from which an increase in stiffness is shown by a circular arc in an anticlockwise direction (Lutman, 1984). The phasor diagrams obtained at 220 and 660 Hz are consistent with increases in susceptance and decreases in conductance at 660 Hz close to threshold, and decreases in both susceptance and conductance at 220 Hz.

Less extensive research has been conducted on the effect of the reflex as recorded at probe frequencies above 660 Hz. It is documented that overall admittance increases when higher probe frequencies are used (Møller, 1961; Dallos, 1964). Weatherby and Bennett (1979) investigating the adult population, and Weatherby and Bennett (1980) and Bennett and Weatherby (1982) investigating the neonatal popluation reported their findings in impedance quantities. Bennett and Weatherby (1979) reported the effect of the reflex on reactance and resistance over a wide range of probe frequencies (200 - 2000 Hz). They found that at probe frequencies above 700 Hz the change in reactance is either a small increase or small decrease, and the change in resistance, always a decrease, is the major effect of the reflex. Thus at higher probe frequencies the reactance effect appears to be smaller than the resistance effect in contrast to lower probe frequencies where reactance changes are the predominant effect of the reflex (Feldman and Williams, 1976; Bennett and Weatherby, 1979). The frequency at which the net resistance change is larger than the net reactance change coincides with the change in direction of overall admittance from a decrease to an increase and is termed the reversing frequency (Bennett and Weatherby, 1979). The effect of these changes in the impedance quantities on the susceptance and conductance components has not been documented in the available literature. The direction and magnitude of susceptance and conductance reflex patterns at higher probe frequencies are of particular interest as they would be expected to reflect the interaction of reactance and resistance under different conditions to those seen at lower probe frequencies. In addition, the susceptance and conductance reflex measurements made at the probe tip for higher probe frequencies need to be documented in terms of magnitude, direction and morphology if they are to be used for clinical investigations, as such investigations do not usually allow for the correction of measured values to the plane of the tympanic membrane or the conversion to impedance quantities. Clinical investigations of the acoustic reflex involve judgements as to whether reflex patterns (direction, magnitude and morphology) are normal or not and thus an expected pattern at high probe frequencies needs to be established.

The morphology of all normal reactance and resistance reflex patterns is monophasic, V or inverted V shaped (Van Camp, Vanpeperstraete, Creten and Vanhuyse, 1975). However, susceptance and conductance reflex patterns may be diphasic in normal ears where baseline resistance/reactance relationships and the reflex induced change meet certain criteria (Creten, Vanpeperstraete, Van Camp and Doclo, 1976; Mangham, Burnett and Lindeman, 1983). Normal diphasic reflexes are differentiated from pathological patterns, such as those reported by

Terkildsen, Osterhammel and Bretlau, (1973) and Jerger and Hayes (1980) in that pathological patterns occur regardless of baseline resistance/reactance relationships. Where baseline conditions are below resonance, diphasic susceptance patterns occur in normal ears only when there is a decrease in resistance associated with an increase in negative reactance as a result of the reflex (Creten et al, 1976). According to the findings presented above (for example Feldman and Williams, 1976; Bennett and Weatherby, 1979) this occurs in normal adult ears at 660 Hz but not at 220 Hz. Consistent with this, is the report that diphasic susceptance patterns have been observed at 660 Hz (Creten et al, 1976; Feldman and Williams, 1976) but not often at 220 Hz (Van Camp et al, 1975). The occurrence of diphasic susceptance patterns at 660 Hz have been related to the intensity of the reflex eliciting stimulus. Positive monophasic changes near to reflex threshold became diphasic, with the centre of the diphasic patterns becoming increasingly negative with further increases in stimulus intensity. As the centre of the reflex is usually used to quantify the amount and direction of the reflex pattern, the direction of the reflex can be said to change from positive to negative values with increases in stimulus intensity. This pattern is evident also in the findings reported by Lutman and Martin (1977), Wilson and McBride (1978) and Lutman et al (1984). This shows that in addition to probe frequency, stimulus intensity is a determiner of the direction of the susceptance reflex patterns. Direction of susceptance reflex patterns has been shown above to depend on the interaction of reactance and resistance values with the reflex activated. As both probe frequency and stimulus intensity are determiners of the direction of susceptance reflex patterns, it follows that stimulus intensity can also influence the interaction between reactance and resistance to determine the direction of susceptance reflex patterns. It appears that with increases in stimulus intensity, the system becomes increasingly stiffened due to contraction of the stapedius muscle, and at some level of contraction, patterns at higher (660 Hz) probe frequencies show the same pattern as is seen for a lower (220 Hz) probe frequency. Wilson and McBride (1978) found that the susceptance direction change at higher intensities occurred for only a few subjects. One possible reason for few observations of these direction changes is that resistance values are more variable across subjects than reactance values for low probe frequencies as suggested by Sprague et al (1981), and it appears to be the amount of stiffness increase caused by the reflex in association with possible, smaller resistance changes, which determines whether susceptance increases or decreases. Another possible reason is that the individual's dynamic range may not have been wide enough to demonstrate this intensity effect. This may account for why some subjects demonstrate the pattern of direction change at suprathreshold levels, whereas others do not. If this were in fact a normal interaction effect, it should be evidenced in all normal subjects if the dynamic range were wide enough. The above studies all recorded reflexes contralaterally, however ipsilateral recording may have allowed for a wider intensity range for exploring this phenomenon, as ipsilateral reflex thresholds are usually lower than contralateral thresholds (Møller, 1962).

Diphasic conductance patterns emerge when baseline functioning has a large resistance component (indicated by notched tympanograms) and the contribution of resistance to overall impedance decreases during the reflex (Van Camp et al, 1975). From these criteria, it is expected that diphasic conductance patterns would be more common at higher probe frequencies. Only a few diphasic conductance patterns were recorded at 660 Hz by Creten et al (1976). As conductance decreases at both of the probe frequencies used in previous investigations where a wide range of intensities has been used (ie 220 and 660 Hz), there has been no account of direction changes as related to stimulus intensity for the conductance component. The limitations in previous studies accounting for the occurrence of diphasic conductance patterns at higher probe frequencies may be because a wide range of stimulus intensities have been used only at probe frequencies up to 660 Hz, where many normal adult ears may be stiffness dominated, and there has been no previous linking of tympanometric configuration and resonant frequencies to reflex patterns. Investigating these aspects may assist in clarifying the occurrence of diphasic conductance patterns, particularly for a wide range of intensities.

Also closely related to the issue of resonance is the relationship between stimulus frequency and how this affects reflex morphology, direction and magnitude. Contradictory findings are reported in the literature regarding the relationship between stimulus frequency and the magnitude of reflex patterns. High frequency stimuli are reported to elicit smaller reflex patterns than low or mid-frequency stimuli by, for example, Wilson and McBride (1978); and Updike and Epstein (1983). Other researchers, however, such as Kaplan, Gilman and Dirks (1977) have found low frequency stimuli to yield the smallest reflex patterns. Lutman and Martin (1979) provide an explanation for why low frequency stimuli may yield smaller reflex patterns as they state that the effect of the reflex is to attenuate frequencies below resonance, and to slightly amplify sounds above resonance. Thus lower intensity levels of low frequency stimuli may reach the cochlea than are presented in the sound field, yielding smaller reflex patterns. Should there be differences in the amount of admittance change at different stimulus frequencies, it would be expected that this would relate to the resonant frequency of the middle ear. It is possible that the contradictions in the available literature have arisen because middle ear resonance was not taken into account in investigating the differential effects of reflex eliciting stimuli. Although Block and Wiley (1986) reported that the magnitude of suprathreshold reflex measurements was affected by the stiffness of the middle ear system as determined by static compliance measures, the extension of this aspect to include resonance as it relates to stimulus frequencies would be interesting and would assist in the interpretation of reflex patterns.

In summary, the magnitude, morphology and direction of the reflex may be influenced by probe frequency, stimulus frequency, stimulus intensity and resonance characteristics although the relationships between these factors has not been clearly shown in the available literature. The aim of the present study was therefore to investigate the interaction between probe frequency, stimulus frequency, stimulus intensity and resonance characteristics of individuals in determining the magnitude, direction and morphology of susceptance and conductance reflex patterns recorded at the probe tip, as is conventional in clinical investigations.

CHAPTER 2
METHODOLOGY: PART ONE

2.1 Aims

The research conducted in part one of the study was exploratory in nature. The investigation aimed to describe susceptance and conductance reflex patterns recorded at the probe tip using three stimulus frequencies (0.5, 1 and 2 kHz) at three probe frequencies (226, 678 and 1000 Hz). Reflex patterns were defined in terms of magnitude, direction and morphology at threshold and saturation, and the pattern of reflex growth. The influence of middle ear resonance (as approximated by natural frequency measurerements) on reflex patterns was also determined.

The specific aims were:

1 To examine the magnitude of the reflex in relation to probe frequency, stimulus frequency, stimulus intensity and middle ear resonance.

2 To examine the direction of the reflex in relation to probe frequency, stimulus frequency, stimulus intensity and middle ear resonance.

3 To examine the morphology of the reflex in relation to probe frequency, stimulus frequency, and stimulus intensity.

2.2 Subjects

Subjects were recruited on a voluntary basis. Some subjects volunteered two ears and others one ear on the basis of their time available. Twenty ears were included from 13 volunteers on this basis, to represent a sample of ears from a normal young adult population. Data was collected from both ears for 7 of the volunteers and from one ear only for 6 of the volunteers. All ears were required to meet the following criteria:

1 HISTORY:

Subjects were required to have no known history of ear pathology or family history of hearing loss.

2 AGE:

To ensure that age related auditory changes did not influence findings subjects were required to be between 18 and 30 years of age.

3 HEARING STATUS:

Hearing thresholds of all subjects were required to be within normal limits (between -10 and 25 dB HL) as defined by Goodman (1965, cited by Yantis, 1985). Air and bone conduction hearing thresholds were required to be within 10 dB to exclude any middle ear disorders not known to the subject. Normal middle ear function was further established on the basis of tympanometry and acoustic reflex measurements. All subjects were required to have single peaked admittance tympanograms at 226 Hz and ipsilateral acoustic reflex thresholds within normal limits (70 to 100 dB HL) as defined by Northern (1980) for 0.5, 1 and 2 kHz stimuli for admittance at 226 Hz probe frequency.

4 SEX:

Equal numbers of male and female subjects were selected due to there being possible anatomical differences between the two sexes which may affect immittance measures at different probe frequencies (Creten, Van de Heyning and Van Camp, 1985).

During the data collection one volunteer absconded and data from 19 ears was analysed.

2.3 Instrumentation

Hearing thresholds were established for all subjects using a GSI 10 Clinical Audiometer, with TDH-50P earphones and B71 bone vibrator. This audiometer, calibrated in dB HL meets the ANSI S.13-1972 standard for audiometers. The instrument used was in general clinical use and therefore annual calibration and regular biological checks ensured that specifications were accurate.

Immittance measurements were made using a GSI 33 version 2 Middle Ear Analyser. This microprocessor based instrument meets the ANSI s3.39 - 1987 standard for acoustic-immittance instruments. Probe frequencies (226, 678 and 1000 Hz) are nominally set at 70 dB HL (Grason Stadler Instruction Manual). Ipsilateral reflex probe and stimulus tones are time multiplexed. For reflex measurements either susceptance or conductance changes can be displayed at one time.

The instrument was calibrated for the specific altitude of the test environment (98 meters above sea level) as recommended by Lilly and Shanks (1981). A calibration check following the manufacturers' instructions was carried out on each day of data collection.

2.4 Test Environment

Hearing threshold testing was conducted in an acoustically treated audiometric suite IAC 109, meeting the SABS 0182 (1982) code of practice. All immittance measurements were conducted in a sound treated environment.

2.5 Procedure

1 Middle ear resonance was approximated through the identification of natural frequency for each subject using the GSI 33 multifrequency tympanometry programme. This programme consists of frequency sweeps (200 to 2000 Hz) at +200 daPa and tympanometric peak (determined from the 226 Hz admittance tympanogram). The frequency at which susceptance is zero or where the phase angle is at a minimum (whichever is lower) is used as an approximation of middle ear resonance (Funasaka and Kumakawa, 1988). In order to ensure that an adequate approximation of resonance was obtained,

susceptance and conductance tympanograms were recorded at this frequency to check for the 3B1G configuration.

2 Acoustic reflexes were recorded for susceptance and conductance at 226, 678 and 1000 Hz probe frequencies for 0.5, 1 and 2 kHz tonal stimuli. The intensity of the reflex eliciting stimulus ranged between 66 and 110 dB HL. All reflex measurements were made in the ipsilateral mode.

Details of acoustic reflex measures are described in terms of:

- Procedural variables
- Procedure.

2.5.1 Procedural variables

The three probe frequencies available on the GSI 33 Middle Ear Analyser were used for the study, namely 226, 678 and 1000 Hertz.

All measurements were made in the ipsilateral mode. Ipsilateral measures are simpler than contralateral measures in that they involve only one ear (Green and Margolis, 1983). In recording ipsilateral reflex patterns, there is the possibility that reflex induced immittance change will be confused with artifacts due to interactions between probe and stimulus tones (Kunov, 1977; Popelka, 1981). However the GSI 33 uses time multiplexed stimuli for ipsilateral recordings shown by Lutman and Leis (1980) to avoid artifacts to a reasonable extent. The added advantage of recording reflexes ipsilaterally is that lower ipsilateral reflex thresholds would allow for a wider range of intensities for each individual and therefore there is more possibility of demonstrating suprathreshold phenomena within the limitations of the output of the equipment and safety to the subject.

Three tonal stimuli were used to elicit the reflex. The frequencies selected were 0.5, 1 and 2 kHz. Several investigators (for example Kaplan et al, 1977; Silman, Popelka and Gelfand, 1978; Wilson and McBride, 1978; Silman, 1979; Thompson, Sills and Recke, 1980) have used 0.5, 1 and 2 kHz in their data collections. These stimulus frequencies are expected to fall below, within and above middle ear resonance, which is expected to be between 650 and 1400 Hz (Colletti, 1977).

Stimulus intensity ranged from levels below expected reflex thresholds (66 dB HL) to the maximum output of the GSI 33 (110 dB HL for 0.5 and 1 kHz and 104 dB HL for 2 kHz). The wide range of stimulus intensities was incorporated to demonstrate any intensity related effects. Previous investigations such as Lutman et al (1984) have also used stimulus intensities up to 110 dB HL. A 4 dB increment size was used. This increment size was selected for convenience (the GSI 33 allows selection of 1,2 and 5 dB increments) and because several previous studies have used a 4 dB step size (for example Wilson and McBride, 1978; Sprague et al, 1981; Greenfield, Wiley and Block, 1985; Block and Wiley, 1986).

The stimulus duration was kept constant at 1.5 seconds for each stimulus presentation. As temporal characteristics were not being investigated it was not necessary to link the amount of admittance change with the time characteristics of the stimulus. Thus stimulus duration was simply kept constant under all conditions and not considered further.

2.5.2 Procedure

2.5.2.1 Air Pressure During Recordings

All reflex measurements were made at tympanometric peak pressure recorded for an admittance tympanogram at a probe frequency of 226 Hz. This meant that the actual air pressure in the ear canal varied across subjects, but for each subject tympanometric peak pressure represented the air pressure at which the measurement device would be most sensitive to the effect of the acoustic reflex.

2.5.2.2 Direction And Magnitude Of Change

The GSI 33 is configured such that reflex measures are baselined, so that the admittance properties of the ear at the specific probe frequency are represented as zero, to allow for easier detection of reflex induced susceptance and conductance change against the noise floor of the equipment as advised by Wiley and Block (1979).

Magnitude and direction of the reflex pattern (positive or negative) was recorded at each intensity level, in mmhos, representing the maximum measured susceptance or measured conductance change during the time course of the reflex.

Grason Stadler have provided magnitude criteria in order to determine reflex thresholds. The magnitude criteria are specific to each probe frequency and are identical for both susceptance and conductance (GSI 33 Instruction Manual).

The GSI criteria are:

- 0.02 mmho at 226 Hz probe frequency
- 0.06 mmho at 678 Hz probe frequency
- 0.09 mmho at 1000 Hz probe frequency.

In addition to these criteria, reflex threshold was determined as the intensity level at which the criterion magnitude could be reproduced and at which further increases in stimulus intensity were associated with further increases in reflex magnitude.

Saturation of the reflex was determined as the intensity level in dB HL at which the largest magnitude of the reflex was observed, and beyond which further increases in stimulus intensity did not yield further increases in magnitude of the reflex.

Diphasic patterns were defined as irregular reflex patterns having a W shape. The minimum criterion magnitude used at any probe frequency to differentiate random from reflex related admittance change (0.02 mmho for 226 Hz) was used to define diphasic patterns for all probe frequencies. Thus the initial or final deviation needed to be more than 0.02 mmho for the irregularity to be defined as a diphasic reflex for the purposes of this study. This was incorporated into the methodology in order to avoid confusing undershoots and overshoots, commonly seen in reflex measurements, with diphasic patterns (Silman and Silverman, 1991). The elicitation of diphasic patterns was repeated to ensure that patterns were reliable and not related to some transient influence from the equipment or the individual.

Where diphasic patterns were observed, three mmho values were recorded, one for each of the extrema. The mmho value at the center point of the reflex was used for quantification of the reflex.

2.5.2.3 Measurement Sequence

The sequence of measurement was kept constant across all subjects. Measurements at 226 Hz probe frequency were made first, followed by 678 Hz and then 1000 Hz measurements.

Within each probe condition, the frequency of the reflex eliciting stimuli was raised. Thus 0.5 kHz measurements were made first, followed by 1 and then 2 kHz measurements.

Within each probe/stimulus condition, susceptance measures preceded conductance measures. The GSI 33 middle ear analyser does not allow for simultaneous recordings of susceptance and conductance reflexes. Nonsimultaneous susceptance and conductance measures were therefore made. Nonsimultaneous recordings have been used by previous researchers (for example Feldman and Williams, 1976). This assumes however, that identical conditions occur across both susceptance and conductance recordings. This assumption may be violated due to physiological changes and possible movement of the probe tip. Such influences were considered to be minimised, although probably not completely eliminated, due to the zeroing of baseline conditions and the linking of reflex patterns to the presentation of the reflex eliciting stimulus over time. These influences are present in most clinical investigations and as the aim of the study was to explain reflex patterns as they might be observed during clinical investigations, they were not considered as inappropriate to the methodology. Intensity was raised in 4 dB steps from 66 dB to the maximum intensity presented.

An interstimulus interval of at least 2 seconds was allowed, as this time interval is sufficient for the stapedius muscle to return to its normal state after contraction (Popelka, 1981).

A total of 18 growth functions were obtained for each ear. This procedure is lengthy, and therefore to avoid confounding results with possible fatigue of the stapedius muscle, sessions were limited to 60 minutes each.

2.6 Data Handling And Data Analysis

The data collection procedure involved recording the amount of susceptance and conductance change in mmho, linked to the activation of the acoustic reflex. Mmho values for each intensity level, for each probe frequency, stimulus frequency and admittance component were recorded. From this large data set of acoustic reflex measures, and the recording of resonance characteristics, specific aspects were extracted for analysis.

2.6.1 Resonant characteristics of ears used in the study

Central tendencies of the resonant frequencies of ears were described by means of summary statistics (Miller, 1975). In order to investigate the effect of resonance on reflex patterns, ears were assigned to one of two groups, one having resonant frequencies below 950 Hz (Group A) and the other having resonant frequencies at or above 950 Hz (Group B). 950 Hz was arbitrarily selected as the cut off between the two groups, to differentiate those ears with low versus high resonant frequencies. These resonant frequency groups were used for analysis of magnitude and direction of reflex change at saturation, and patterns of reflex growth above threshold.

2.6.2 Direction of reflex induced change at threshold

The distribution of the direction of reflex patterns (+ or - of susceptance and conductance) across the probe and stimulus frequencies was shown by means of frequency counts.

2.6.3 Intensity level at which saturation was reached

Central tendencies were described for the intensity level at which saturation was reached, for each probe and stimulus condition, using summary statistics. Any possible differences between the stimulus frequencies in terms of the intensity at which saturation was reached was examined for each probe frequency using multifactor Analysis of Variance (ANOVA) computations (Fitz-Gibbon and Morris, 1987). Any significant ANOVA results were investigated further by means of multiple range analyses for the means.

2.6.4 Magnitude and direction of reflex patterns recorded at saturation

The magnitude (mmho) and direction (+ or - from baseline) for each component at saturation was examined to determine the relative contributions of susceptance and conductance across probe and stimulus frequencies.

Summary statistics and multiple box and whisker plots (Miller, 1975) were used to describe the central tendencies of these values. Any possible differences between the stimulus frequencies in terms of the magnitude and direction of reflex patterns at saturation for each probe frequency were examined using ANOVA (Fitz-Gibbon and Morris, 1987). Any significant ANOVA results were investigated further by means of multiple range analyses for the means.

In addition, measures of central tendency (summary statistics and multiple box and whisker plots) were used to describe the reflex patterns at saturation for each of the resonant frequency groups.

2.6.5 Diphasic reflex patterns

Frequency counts were made for diphasic reflex patterns for each probe/stimulus condition for each component. The number of diphasic reflex patterns which occurred in association with direction changes was also recorded.

2.6.6 Classification of growth functions

Reflex magnitude as a function of intensity was classified as either:

Type 1:	The direction of change (susceptance or conductance) remained constant across the intensity range .
Type 2:	The direction of the reflex changed at higher intensity levels of the reflex activating stimuli. That is positive values at threshold changed to negative values at suprathreshold levels or vice versa.

Counts were made of the number of times each growth function occurred at each probe and stimulus frequency. Chi square analysis was used to investigate whether there was any relationship between stimulus frequency and reflex growth patterns observed at each probe frequency (Fitz-Gibbon and Morris, 1987). This was done for the group of ears as a whole and for each resonant frequency group to investigate the relationship between resonant frequency and reflex growth across the stimuli.

All summary statistics, multiple box and whisker plots, and analysis of variance were obtained using the Statgraphics Programme(1985-1989,STSC).

CHAPTER 3
RESULTS AND DISCUSSION: PART ONE

3.1 Resonance Characteristics Of Ears Used In The Study

A wide range of resonant frequencies were recorded (see Table 2 and Figure 1). The range, from 700 to 1600 Hz, is wider and slightly higher than that documented for normal subjects by Colletti (1977) who reported a range from 650 to 1400 Hz. The mean resonant frequency (850 Hz) is however, lower than that reported by Colletti (ie 1000 Hz).

Table 2: **Summary statistics to show the resonance characteristics of subjects used in the study**

Mean	892 Hz
Median	850 Hz
Mode	1000 Hz
SD	110 Hz
Max	1600 Hz
Min	700 Hz
Range	900 Hz

When divided on the basis of resonant frequency, group A (resonance below 950 Hz) consisted of 10 ears and group B (resonance at or above 950 Hz) consisted of 9 ears. Appendix A provides the resonant frequencies etimated for each subject.

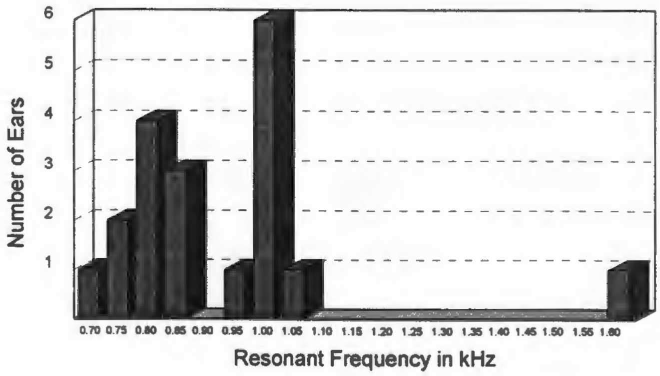


Figure 1: **Histogram to show the distribution of resonant frequencies**

3.2 Direction Of Reflex Induced Change At Threshold

A clear pattern of decreases in susceptance and conductance at 226 Hz probe frequency, increases in susceptance and decreases in conductance at 678 Hz probe frequency and increases in susceptance and conductance at 1000 Hz probe frequency was obtained for the probe tip measurements (see Table 3).

Table 3 **Direction of reflex change (positive or negative) at threshold across probe and stimulus frequency**

Probe Frequency (Hz)	226			678			1 000		
Stimulus Frequency (kHz)	0.5	1	2	0.5	1	2	0.5	1	2
-B-G	19	19	19	1	2	2	0	0	0
+B-G	0	0	0	18	17	17	2	2	2
+B+G	0	0	0	0	0	0	17	17	17

-B-G represents decreases in susceptance and in conductance
+B-G represents increases in susceptance and decreases in conductance
+B+G represents increases in susceptance and in conductance

All exceptions to these patterns (most of which arose from those ears with higher resonant frequencies), showed the same trend in terms of the direction of the reflex, only the transition from negative to positive susceptance occurred at higher probe frequencies than for the majority of ears. As a result, as probe frequency was raised in the present study, the number of exceptions to the general pattern increased. The exceptions to the general pattern always reflected the dominant pattern observed at lower probe frequencies. That is, the 5 exceptions at 678 Hz probe frequency are all -B-G patterns, the general pattern recorded at 226 Hz probe frequency (see subjects 6 and 17 in Appendix B). Likewise the 6 exceptions at 1000 Hz probe frequency are all +B-G patterns the general pattern recorded at 678 Hz probe frequency (see subjects 5, 16 and 17 in Appendix B). The ear which had the highest resonant frequency (Subject 17) was one of the exceptions to the general pattern, showing susceptance and conductance decreases (-B-G) at both 226 and 678 Hz; and susceptance increases and conductance decreases (+B-G) at the 1000 Hz probe frequency for all three stimuli. This suggests that for this ear the reflex had a similar effect at 226 and 678 Hz and showed the transition to increased susceptance at 1000 Hz. This example indicates that the direction changes along the probe frequency continuum occur in systematic ways, but that the actual probe frequency at which the shift occurs may be individually determined. The pattern seen for the majority of ears and the exceptions, suggest that baseline transmission properties (that is without the reflex activated) are determiners of the reflex direction at threshold. As tympanometric information was not obtained at each probe frequency, a correlation between baseline conditions and reflex directions at threshold cannot be made, but would be interesting to investigate further.

Reflex patterns at threshold for the two lowest probe frequencies (-B-G at 226 Hz and +B-G at 678 Hz) are the same as those recorded by Feldman and Williams (1976) and Lutman and Martin (1977). Each of these three studies (the two cited and the present) incorporated different methodologies preventing detailed comparisons across them. However, both the cited studies suggest that the patterns at these two probe frequencies result from an increase in stiffness (negative reactance) due to the activation of the reflex. It follows then, that this is possibly the same effect being recorded in the present study at the 226 and 678 Hz probe frequencies.

The increase in both susceptance and conductance at the 1000 Hz probe frequency has not been previously reported in the literature. Lutman and Martin (1979) and Lutman (1984) showed the effect of the reflex as being an increase in stiffness with a constant resistance, represented as a circular arc for phasor diagrams. Movement along the circumference of the arc in an anticlockwise direction represents the increase in stiffness. It may be possible to map the increases in susceptance and conductance, observed in the present study at the 1000 Hz probe frequency onto the phasor diagram, as presented by these researchers. This would lend support to the notion that the effect of the reflex at the 1000 Hz probe frequency is consistent with a constant resistance, stiffness change model. This could not be done for the data obtained as baseline transmission properties without the reflex activated were not obtained at the 1000 Hz probe frequency. However, it would be interesting to investigate this pattern of increased susceptance and conductance against the constant resistance, stiffness change model to investigate the effect of the reflex on impedance properties. The advantage of this means of analysis over other methodologies (which incorporate calculations of reactance and resistance values rather than diagrammatic representations) is that phasor plots of measured susceptance and conductance have similar shapes to phasor plots of compensated susceptance and conductance (Lutman and Martin, 1979). Thus no correction of measurements to the plane of the tympanic membrane is required (Creten, Van Camp, Maes and Vanpeperstraete, 1981). Correction to the plane of the tympanic membrane is prone to large errors (Wiley and Block, 1979; Lutman, 1993) and there is little consensus in the literature concerning the most suitable means for achieving this. Simply examining the shape of phasor plots may assist in establishing whether or not the reflex pattern at 1000 Hz is related to increases in stiffness, and constant resistance. This aspect was developed further in the second part of the study.

3.3 Intensity Level At Which Saturation Was Reached

A significant difference (see Table 4) was found between the stimulus frequencies in terms of the intensity levels at which saturation was reached for susceptance at 226 Hz and for conductance at 678 and 1000 Hz probe frequencies.

Table 4: **Analysis of variance of saturation for each stimulus, for each component and probe frequency. Multiple range analysis for the relationship between stimulus frequencies is shown by gray shading**

	SUSCEPTANCE					CONDUCTANCE				
Source	**F**	**P**	**Multiple Range**			**F**	**P**	**Multiple Range**		
226 Hz	5.403	0.0068	0.5 kHz	▨		0.038	0.9632	0.5 kHz	▨	
			1 kHz	▨	▨			1 kHz	▨	
			2 kHz		▨			2 kHz	▨	
678 Hz	0.263	0.7699	0.5 kHz	▨		21.694	O.0000	0.5 kHz	▨	
			1 kHz	▨				1 kHz		▨
			2 kHz	▨				2 kHz		▨
1000Hz	0.299	0.7427	0.5 kHz	▨		4.209	O.0200	0.5 kHz	▨	
			1 kHz	▨				1 kHz	▨	▨
			2 kHz	▨				2 kHz		▨

It is unclear why this effect of stimulus frequency was significant for only some of the conditions and not all of them.The maximum intensity level presented was different at 2 kHz (104 dB HL) as compared to the 0.5 and 1 kHz stimuli (110 dB HL). In spite of this, mean saturation levels could be compared across stimuli as they are below the maximum levels possible (see Table 5). In all cases of significant ANOVAs, the 0.5 and 1 kHz stimuli had higher mean saturation levels than the 2 kHz stimulus. Similar findings of lower saturation levels for high frequency stimuli are reported by Wilson and McBride (1978) and Updike and Epstein (1983). However, statistical analysis by means of multiple range tests (Table 4) showed that 0.5 and 1 kHz, as well as 1 and 2 kHz tended to show similar patterns, showing considerable overlap across these three stimulus frequencies.

Table 5: **Mean intensity levels in dB HL at which saturation was recorded for each probe and stimulus frequency. The range of values is recorded in brackets**

Probe Frequency	Stimulus Frequency	Saturation Susceptance	Saturation Conductance
226 Hz	0.5 kHz	105 (94 - 110) dB HL	100 (90 - 110) dB HL
	1 kHz	106 (98 - 110) dB HL	101 (90 - 110) dB HL
	2 kHz	102 (94 - 104) dB HL	101 (90 - 104) dB HL
678 Hz	0.5 kHz	96 (90 - 110) dB HL	108 (98 - 110) dB HL
	1 kHz	96 (82 - 110) dB HL	109 (102 - 110) dB HL
	2 kHz	98 (90 - 104) dB HL	103 (94 - 104) dB HL
1000 Hz	0.5 kHz	102 (94 - 110) dB HL	104 (90 - 110) dB HL
	1 kHz	103 (94 - 110) dB HL	106 (90 - 110) dB HL
	2 kHz	102 (94 - 104) dB HL	101 (90 - 104) dB HL

3.4 Magnitude And Direction Of Reflex Patterns At Saturation

The direction of the reflex patterns at saturation are identical to those at threshold for the 226 and 678 Hz probe frequencies (compare Table 3 and Table 6), whereas at 1000 Hz probe frequency the direction of conductance reflexes at saturation were sometimes negative whereas at reflex threshold the direction was mostly positive. This indicates a direction change with increasing stimulus intensity. This aspect will be discussed further below in relation to patterns of reflex growth. Clearly shown in Table 6 is that at saturation, the 1000 Hz probe frequency yields positive susceptance reflex patterns and either positive or negative conductance reflex patterns.

Table 6: **Direction of reflex change (positive or negative) at saturation across probe and stimulus frequency**

Probe Frequency (Hz)	226			678			1 000		
Stimulus Frequency (kHz)	0.5	1	2	0.5	1	2	0.5	1	2
-B-G	19	19	19	1	2	2	0	0	0
+B-G	0	0	0	18	17	17	11	14	6
+B+G	0	0	0	0	0	0	8	5	13

-B-G represents decreases in susceptance and in conductance
+B-G represents increases in susceptance and decreases in conductance
+B+G represents increases in susceptance and in conductance

Clear trends in terms of the magnitude of the susceptance and conductance changes across probe and stimulus frequencies were obtained for 226 and 678 Hz probe frequencies. The magnitude of the reflex patterns at 226 Hz are relatively small. Mean susceptance and conductance reflex magnitudes are fairly similar to each other across stimulus frequencies at this probe frequency. A small variation in reflex patterns at this

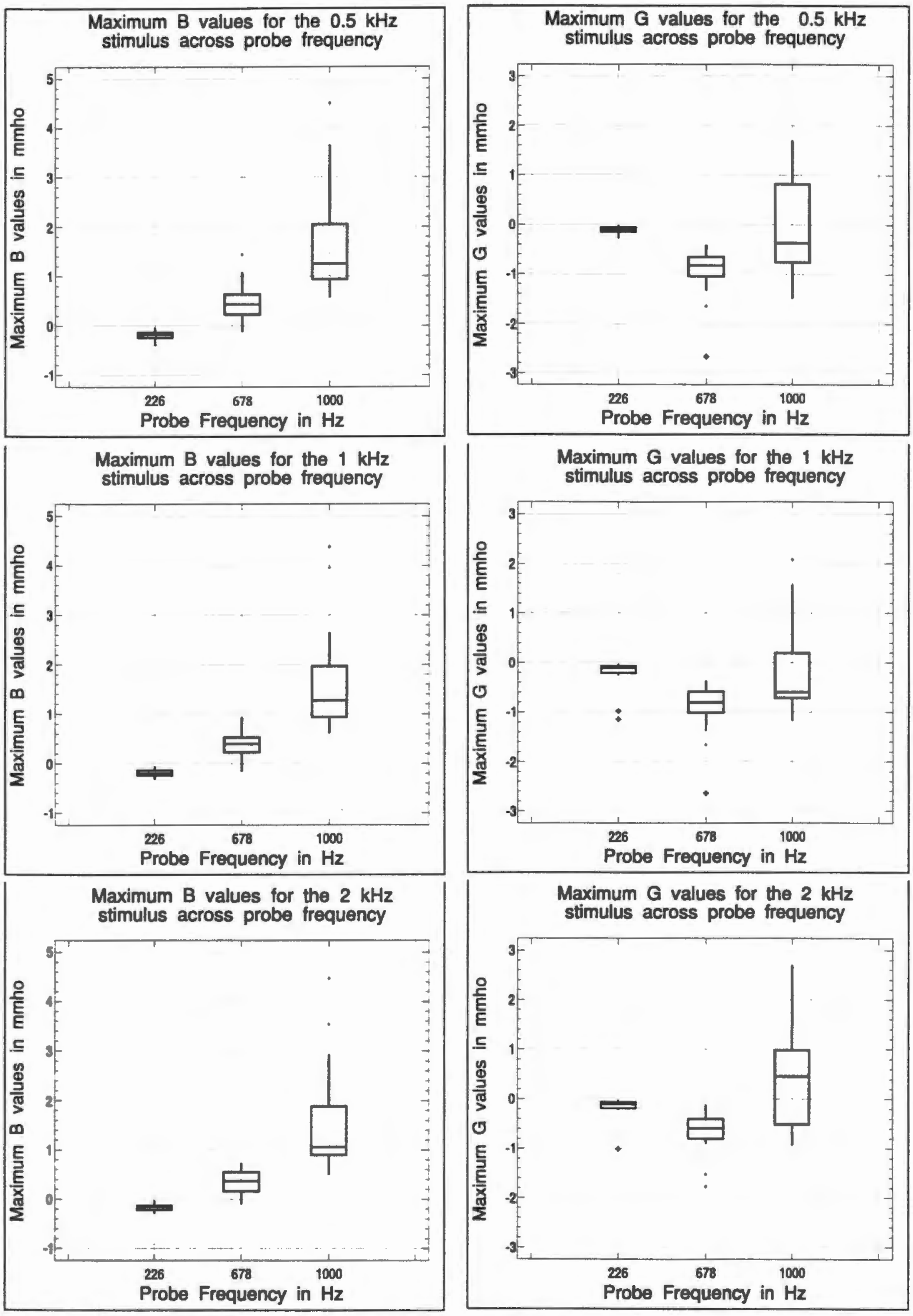


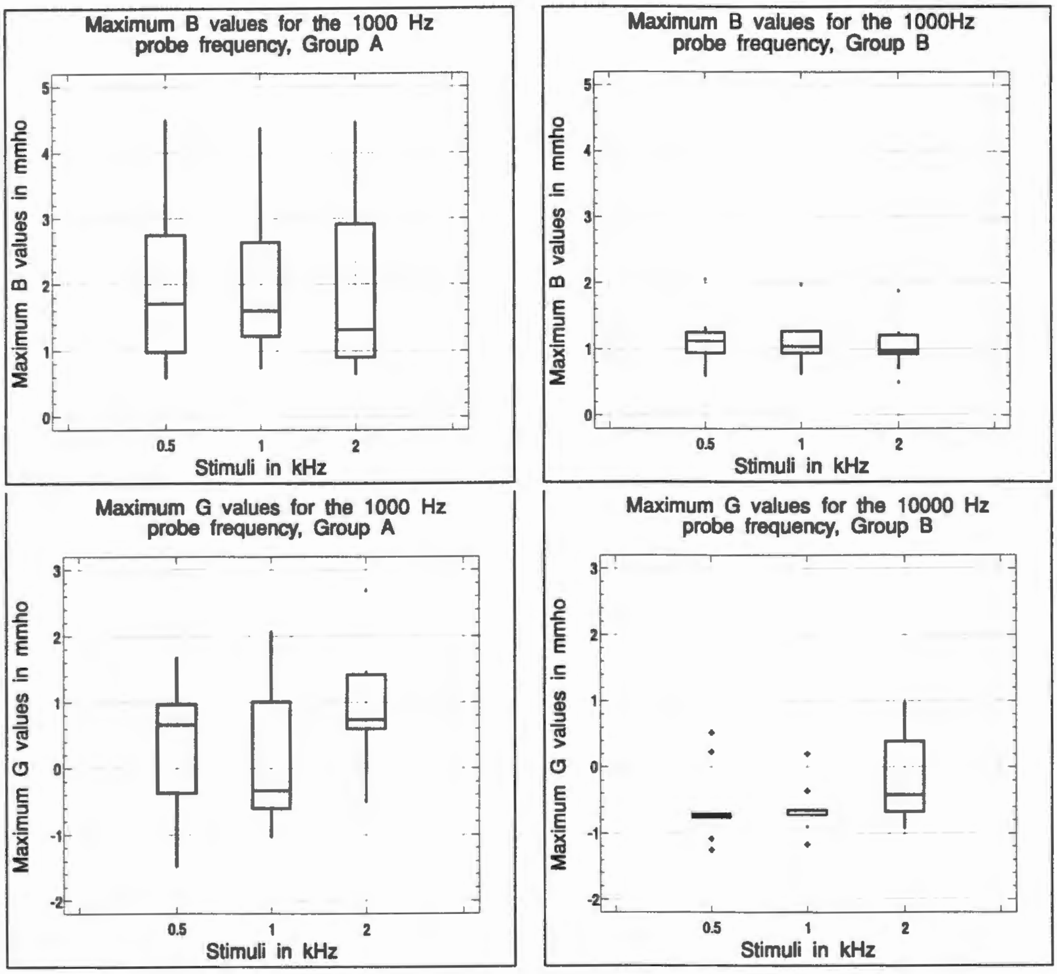
Figure 2: **Multiple Box & Whisker plots to show the maximum susceptance (B) and conductance (G) values recorded across probe frequency and simulus frequency**

probe frequency is shown by the relatively narrow range of maximum susceptance and conductance scores for each of the stimulus frequencies shown in the multiple box and whisker plots (Figure 2) and in the values in Table 7. At 678 Hz mean susceptance magnitudes, in absolute value, were smaller than mean conductance magnitudes, and the relative magnitudes of both the susceptance and conductance components are larger than those at 226 Hz. The results obtained at these two probe frequencies in terms of both direction and magnitude are in excellent agreement with previous reports (for example Feldman and Williams, 1976; Wilson and McBride, 1978).

Table 7: **Summary statistics for maximum susceptance (B) and conductance (G) values recorded in mmho for each probe frequency and stimulus frequency (n=19)**

			Mean	Median	Mode	SD	Min	Max	Range
226 Hz	0.5 kHz	B	-0.18	-0.18	-0.27	0.08	-0.04	-0.40	0.36
		G	-0.11	-0.10	-0.15	0.07	-0.02	-0.28	0.26
	1 kHz	B	-0.18	-0.19	-0.24	0.07	-0.05	-0.32	0.27
		G	-0.21	-0.11	-0.12	0.30	-0.02	-1.15	1.13
	2 kHz	B	-0.16	-0.16	-0.22	0.07	-0.03	-0.29	0.26
		G	-0.16	-0.11	-0.09	0.21	-0.02	-1.01	0.99
678 Hz	0.5 kHz	B	0.47	0.43	0.43	0.36	-0.11	1.44	1.55
		G	-0.96	-0.83	-1.05	0.51	-0.42	-2.67	2.25
	1 kHz	B	0.37	0.40	0.33	0.25	0.93	-0.15	1.08
		G	-0.94	-0.81	-0.74	0.52	-0.37	-2.64	2.27
	2 kHz	B	0.35	0.37	0.64	0.24	-0.10	0.73	0.83
		G	-0.64	-0.59	-0.56	0.41	-0.12	-1.77	1.65
1000 Hz	0.5 kHz	B	1.60	1.25	1.19	1.04	0.58	4.50	3.92
		G	-0.11	-0.37	-0.73	0.94	-1.48	1.69	3.17
	1 kHz	B	1.61	1.27	1.23	1.03	0.62	4.38	3.76
		G	-0.20	-0.60	-0.72	0.91	-1.17	2.08	3.25
	2 kHz	B	1.40	1.06	1.00	1.07	0.50	4.47	3.97
		G	0.40	0.46	0.39	0.92	-0.93	2.69	3.62

At the 1000 Hz probe frequency mean susceptance magnitudes were larger than mean conductance magnitudes, and there was a wide variation in the results obtained. The wide variation in results occurred for both of the components and for all of the stimuli as shown in the spread



Maximum B values for the 1000 Hz probe frequency, Group A

Maximum B values for the 1000Hz probe frequency, Group B

Maximum G values for the 1000 Hz probe frequency, Group A

Maximum G values for the 10000 Hz probe frequency, Group B

Figure 3: Maximum susceptance (B) and conductance (G) values recorded at the 1000Hz probe frequency across stimulus frequencies for each group. Group A represents those with resonant frequencies less than 950Hz; group B represents subjects with resonant frequencies at or above 950Hz

of results in Figure 2. The wide range for conductance could be expected given the results shown in Table 6, that both positive and negative conductance reflex patterns were observed at saturation. No significant differences in the reflex patterns at saturation were seen between the stimulus frequencies (see Table 8) for any of the probe frequencies, even though for the 1000 Hz probe frequency, measures of central tendency indicated negative reflex patterns for 0.5 and 1 kHz stimuli, and positive reflex patterns for the 2 kHz stimulus.

Table 8: **Summary of ANOVA values investigating differences between reflex patterns for the stimulus frequencies at saturation for each of the probe frequencies**

	SUSCEPTANCE		CONDUCTANCE	
Source	**F**	**P**	**F**	**P**
226 Hz	0.29	0.7945	0.997	0.3758
678 Hz	0.946	0.3946	2.586	0.0846
1000 Hz	0.075	0.9274	2.381	0.1021

Investigating whether middle ear resonance influenced the direction of reflex patterns at saturation for each of the probe frequencies (Table 9) it is apparent that this is the case at the highest probe frequency only as seen by positive conductance values for group A and negative conductance values for group B at the 1000 Hz probe frequency.

Table 9: **Mean Maximum susceptance (B) and conductance (G) values for the two groups of ears, divided on the basis of resonance characteristics.**

		226 Hz		678 Hz		1000 Hz	
		Group A	**Group B**	**Group A**	**Group B**	**Group A**	**Group B**
SUSCEPTANCE	**0.5 kHz**	-0.19	-0.17	0.51	0.43	2.01	1.15
	1 kHz	-0.19	-0.17	0.45	0.29	2.06	1.12
	2 kHz	-0.16	-0.16	0.36	0.33	1.90	1.04
CONDUCTANCE	**0.5 kHz**	-0.12	-0.11	-1.14	-0.77	0.30	-0.58
	1 kHz	-0.23	-0.20	-1.09	-0.76	0.19	-0.63
	2 kHz	-0.21	-0.10	-0.76	-0.51	0.91	-0.15

Group A: Resonant frequencies less than 950Hz (n=10)
Group B: Resonant frequencies greater than 950Hz (n=9)

The results for each of the resonant frequency groups for the 1000 Hz probe frequency only are therefore displayed as multiple box and whisker plots in Figure 3. The magnitude of reflex patterns at this probe frequency for each resonant frequency group is also shown in Figure 3.

Those ears with lower resonant frequencies have a wider range of susceptance and conductance values than those ears with higher resonant frequencies, with the possible exception of the 2 kHz stimulus.

Susceptance reflexes are positive for both resonant frequency groups. Group B (ears with high resonant frequencies and assumed stiffness dominated systems at 1000 Hz) show mostly negative conductance patterns at all stimulus frequencies, although the 2 kHz stimulus has more positive values recorded than the other two stimulus frequencies. Group A (ears with lower resonant frequencies and assumed mass dominance at 1000 Hz) show mostly positive conductance patterns at all stimulus frequencies, although the distribution of results indicates more negative conductance values for the 1 kHz stimulus than for the other two stimuli.

It appears from this that at the 1000 Hz probe frequency, magnitude and direction of reflex patterns at saturation are influenced by middle ear resonance. Specifically the magnitude of susceptance reflex patterns and the magnitude and direction of conductance patterns appear to be related to baseline transmission characteristics. This would be interesting to investigate more directly. In the present study, only a gross indication of underlying transmission characteristics at the 1000 Hz probe frequency was made by means of measuring middle ear resonance. As shown in Figure 1, even within the two resonant frequency groups to which each of the ears was assigned, there was a wide range of results. To clarify and explain the present findings, it would be useful to relate underlying transmission characteristics (for the probe frequency used for recording) to the reflex patterns observed at both threshold and suprathreshold levels.

3.5 Diphasic Reflex Patterns

A total of 96 diphasic reflex patterns were recorded during the data collection, out of the total of 4332 reflex patterns measured. There are clearly more frequent occurrences of diphasic reflex patterns at higher probe frequencies (see Table 10).

Table 10: **Frequency counts of diphasic reflex patterns recorded at each probe and stimulus frequency for susceptance (B) and conductance (G)**

	Probe Frequency					
	226 Hz		678 Hz		1000 Hz	
Stimulus Frequency	B	G	B	G	B	G
0.5 kHz	0	1	2	2	2	19
1 kHz	0	3	4	4	2	24
2 kHz	2	0	9	2	8	12
TOTALS:	2	4	15	8	12	55

Consistent with previous accounts, (for example, Van Camp et al, 1975; Creten et al, 1976; Bennett and Weatherby, 1979; Mangham et al, 1983) diphasic patterns were seen to occur more frequently at higher probe frequencies. Very few diphasic patterns (6% of the total number of diphasic patterns) were recorded at the 226 Hz probe frequency. 24% of the total diphasic patterns recorded occurred at the 678 Hz probe frequency, of these, most were for the susceptance component. 70% of the diphasic patterns recorded were seen at the 1000 Hz component, and of these, 82% were for the conductance component. Appendix C contains details of probe frequency, stimulus frequency and stimulus intensity for each of the diphasic reflexes observed.

The occurrence of diphasic susceptance reflex patterns at 678 Hz is consistent with the reports in the literature (for example Wilson and McBride, 1978 and Creten et al, 1976). However, contrasting with these previous accounts, the diphasic susceptance patterns recorded in the present study were not associated with changes in the direction of reflex patterns along the stimulus intensity continuum (see Table 13 below, which indicates no direction change for susceptance along the growth functions). The reasons for not observing this phenomenon for susceptance at 678 Hz probe frequency in the present study are unclear, but may have related to methodological issues. However, most of the diphasic conductance patterns observed at 1000 Hz probe frequency occurred at the midintensity range (98 - 102 dB HL), and were associated with direction changes (see Tables 11 and 12).

Table 11: Diphasic conductance patterns observed at 1000 Hz probe frequency, divided into those associated with direction changes and those not.

Stimulus Frequency	Direction Change	No Direction Change
0.5 kHz	12	7
1 kHz	22	2
2 kHz	10	2

Monophasic conductance reflexes near to threshold became diphasic with increases in stimulus intensity, and with further increases in stimulus intensity, the central extremum increased in amplitude and the direction of the reflex changed from positive to negative. An example is provided in Figure 4 (reflex growth type 2) in section 3.6 below. As mentioned in chapter 1, diphasic susceptance and conductance reflexes have been associated with interactions between resistance and reactance values at the lateral surface of the tympanic membrane (Van Camp et al, 1975; Creten et al, 1976; Mangham et al, 1983). The present findings cannot be directly compared to those reported in the literature as probe tip susceptance and conductance reflex patterns cannot be converted to meaningful reactance and resistance values without correcting for ear canal volume (Wiley and Block, 1979; Van Camp, Creten, Van de Heyning, Decraemer and Vanpeperstraete, 1983).

Table 12: **Intensity level at which diphasic reflexes were recorded across probe frequency and components. The number of occurrences at each intensity is recorded**

	Probe Frequency					
	226 Hz		678 Hz		1000 Hz	
dB HL	B	G	B	G	B	G
66						
70	1				1	1
74					1	
78				2		
82	1			2	3	1
86				2	1	1
90		1	1		1	6
94			2		2	7
98		1	2		1	13
102			3			10
104			3	1	2	2
106		1	3			8
110		1	1	1		6

Rather than examining the relationship between underlying resistance and reactance and diphasic patterns, the present investigation was concerned with the distribution of diphasic reflexes. However, the distribution of diphasic relfexes over the midintensity range appears to be consistent with explanations reported in the literature.

It appears that direction changes which occurred with increasing stimulus intensity in the present study may be related to increases in negative reactance. As negative reactance increases during the reflex, certain values of reactance may be reached which interact with the resistance in the system to generate diphasic patterns. The results suggest that for a certain interval of the stimulus intensity the resistance value during the reflex is larger than the reactance value resulting in diphasic conductance patterns, and then with further increases in stimulus intensity the reactance value becomes larger, no longer interacting with resistance, so that conductance reflexes are monophasic decreases. This explanation is consistent with accounts by Bennett and Weatherby (1979) and Mangham et al (1983) as to the conditions leading to diphasic reflex patterns.

Although the majority of diphasic reflex patterns at 1000 Hz probe frequency were associated with direction changes, there were occurrences of diphasic susceptance and conductance reflex patterns at all three probe frequencies which were not associated with direction changes. Although generally consistent with previous accounts (a few diphasic conductance reflex patterns at 226 Hz, and diphasic susceptance patterns at 678 Hz were reported by Creten et al, 1976 and Wilson and McBride, 1978), diphasic susceptance reflex patterns have been associated with direction changes at 678 Hz, and it is not clear whether the dynamic range in the present study was insufficient to demonstrate direction changes, or whether the phenomenon of diphasic reflex patterns can occur independently of direction changes. The diphasic conductance reflex patterns at 678 and 226 Hz are difficult to interpret in terms of direction changes as the direction is usually negative at threshold and suprathreshold intensity levels at both of these probe frequencies (see discussion below in section 3.6).

Creten et al (1976) differentiated between diphasic reflexes due to pathology and those occurring in normal ears due to the underlying resistance/reactance relationship by altering the resistance/reactance relationship in the uncontracted (baseline) condition. As mentioned in chapter 1, this can be done either by changing the probe frequency or by varying the air pressure in the external auditory meatus. Pressure variations stiffen the tympanic membrane, and recording the reflex under these conditions in normal ears should result in monophasic changes. Diphasic changes due to pathology are expected to emerge even at low probe frequencies (Terkildsen et al, 1973; Djupesland and Kvernvold, 1975) or where pressure is varied in the external auditory meatus (Creten et al, 1976). There was no further investigation in this part of the study as to whether these were related to pathology or to the baseline transmission properties. This is of interest as it would add to the explanation of the occurrence of normal diphasic reflexes. This was examined further in part two.

3.6 Classification Of Growth Functions

In addition to the two types of reflex growth function described in Chapter 2, a third pattern of reflex growth, not previously reported in the literature, was observed. Termed Type 3 for the purposes of this study, these growth functions demonstrated a marked decrease in the magnitude of the reflex, but no direction change relative to the direction at threshold. To differentiate such growth functions from Type 1, a decrease of more than 30 %, relative to the magnitude at saturation was required.

Table 13: **Frequency counts of the occurrence of each type of reflex growth functions, across probe frequency and components**

Classification of Growth Functions	Probe Frequency					
	226 Hz		678 Hz		1000 Hz	
	B	G	B	G	B	G
Type 1	57	57	57	57	57	11
Type 2	0	0	0	0	0	35
Type 3	0	0	0	0	0	11
Totals:	57	57	57	57	57	57

This distinction between Type 1 and Type 3 was decided arbitrarily, but was considered to be of interest given the exploratory nature of the study and the lack of previous reports of this in the literature. An example of each type of growth function is presented in Figure 4. For both components at 226 and 678 Hz, and for the susceptance component at 1000 Hz probe frequencies, the growth functions were simple in that growth above threshold is in the same direction as the change at threshold, as shown in Table 13. For conductance at 1000 Hz however, all three types of reflex growth functions were recorded. It can be seen that Type 2

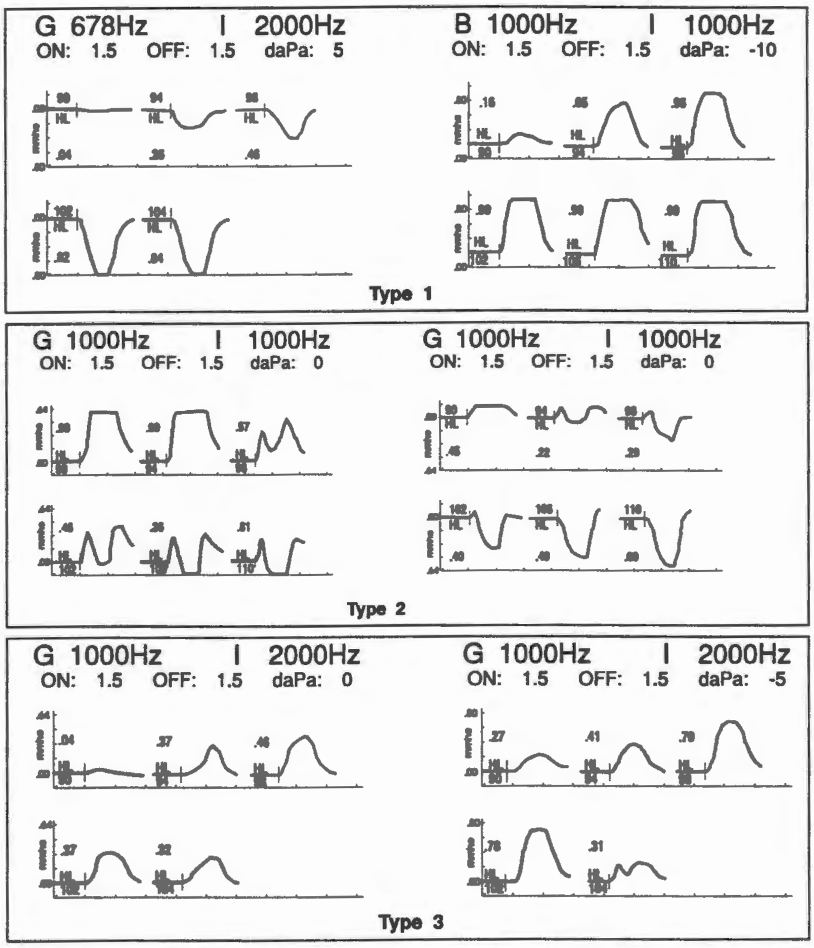


Figure 4: Examples of reflex growth classified according to criteria presented in the text.

patterns are the most common for the 0.5 and 1 kHz stimuli, and that a more even distribution across growth function types was found for the 2 kHz stimulus (see Table 14).

Table 14: Distribution of reflex growth patterns across stimulus frequency for conductance at 1000 Hz probe frequency

	Stimulus Frequency		
	0.5 kHz (n=19)	**1 kHz** (n=19)	**2 kHz** (n=19)
Type 1	3	2	6
Type 2	12	15	8
Type 3	4	2	5
	X^2= 5.71 df = 4 X^2 (crit) = 9.49 (p = 0.05)		

The results of the Chi-square analysis however, also presented in Table 14, showed that the difference between stimulus frequencies was not statistically significant. The investigation of the possible influence of middle ear resonance on the type of reflex growth function observed was carried out for conductance at the 1000 Hz probe frequency only, as all subjects demonstrated the same types of reflex growth for the other probe frequency/component conditions. The results of this are shown in Table 15.

Table 15: **Growth functions observed for the 1000 Hz probe frequency, conductance combination, examined in terms of resonant frequency groups**

	Stimulus Frequency							
	Group A				**Group B**			
TYPE	**0.5 kHz**	**1 kHz**	**2 kHz**	**TOTAL**	**0.5 kHz**	**1 k Hz**	**2 kHz**	**TOTAL**
Type 1	2	0	4	6	2	4	3	9
Type 2	5	9	3	17	7	6	5	18
Type 3	3	1	3	7	1	1	2	4
TOTAL	10	10	10	30	9	9	9	27
	$x^2 = 8.22$ df = 4 x^2 (crit) = 9.49 ($p = 0.05$)				$x^2 = 1.43$ df = 4 x^2 (crit) = 9.49 ($p = 0.05$)			

There is a tendency for direction changes (Type 2 growth functions) to occur for both groups. Stimulus frequency does not appear to be a significant factor in determining reflex growth for either resonant frequency group. Overall patterns of reflex growth are very similar across the two groups. This may have arisen because all ears are normal and differences in resonance between the ears in each group may not have been large enough to demonstrate any possible influence from middle ear resonance on reflex growth for these three stimuli.

The observation of the direction change phenomenon for the conductance component at 1000 Hz is interesting in that previously only observation of direction changes for susceptance at 678 Hz have been reported. Although there are differences in methodology between previous investigations and the present one, these results indicate that the phenomenon of direction change can occur for conductance reflex patterns. The direction change suggests that the reactance change becomes bigger as the stapedius muscle contracts more strongly so as to produce different relationships between resistance and reactance values at low and high stimulus intensities. In order to examine this further, the reactance values associated with specific direction changes in conductance need to be examined. Phasor plots of susceptance and conductance at rest and with the reflex activated would allow for an examination of the effect of the reflex on reactance and resistance values as direction changes in conductance occur.

It appears that the reflex magnitude, direction and morphology are all influenced largely by the acoustic properties of the middle ear in the baseline condition as well as the resistance and reactance relationship when the reflex is activated. Probe frequency, as a major determiner of baseline reactance/resistance relationships, plays a major role in determining the effect of the reflex, as does stimulus intensity. However, it appears not to be probe frequency per se which determines the effect of the reflex, but rather the underlying resistance/reactance relationship and how this changes during the activation of the reflex. These issues were investigated further in the second part of the study using probe frequencies close to individually apporoximated resonant frequencies; phasor plots of reflex growth at a 1000 Hz probe frequency and investigations of diphasic reflexes under varied baseline conditions.

CHAPTER 4
METHODOLOGY: PART TWO

The aim of the second part of the study was to investigate the relationship between transmission properties of the middle ear without the acoustic reflex and the direction and morphology of susceptance and conductance reflexes measured at the probe tip.

4.1 Hypotheses

1 Transmission properties without the reflex will determine the direction of susceptance and conductance reflexes at threshold and suprathreshold levels in the following way:

Increases in susceptance and conductance (+B+G) at reflex threshold occur where the probe frequency is in the region of resonance.

Increases in susceptance and decreases in conductance (+B-G) at reflex threshold occur where the probe frequency is below resonance.

Increases in susceptance and decreases in conductance (+B-G) at suprathreshold levels relative to increases in susceptance and conductance (+B+G) at reflex threshold occur where the probe frequency is in the region of resonance.

2 The susceptance and conductance reflex growth functions measured at the probe tip represented on phasor diagrams indicate increases in stiffness (negative reactance) and constant resistance, regardless of the susceptance / conductance reflex classification observed.

3 Diphasic reflex patterns recorded in normal ears at 1000 Hz probe frequency can be altered to monophasic shapes if the underlying resistance/reactance relationship is altered so that reactance assumes a larger negative value.

4.2 Subjects

As for the first part of the study, subjects were chosen to represent a sample of normal young ears. 30 subjects were selected according to the same criteria as the subjects used in part one (see chapter 2 for specific criteria).

One additional consideration was made for this stage of the investigation, which related to subject selection. Hall (1979) and Creten et al (1985) suggest that interaural differences in normal ears are very small. As it was observed in part one of the study that there is a wide variation within a normal group for the 1000 Hz probe frequency, only one ear was used from each subject to allow for a wider spread of normal ears and prevent possible duplication of results.

4.3 Materials

Hearing thresholds in the selection of subjects were established using a GSI 16 Clinical Audiometer, with TDH-50P earphones and B71 bone vibrator. This audiometer is calibrated in dB HL and meets the ANSI s.26-1981 standard for audiometers.

Immittance measures were made using the same GSI 33 version 2 Middle Ear Analyser described in Chapter 2. The same calibration checks were carried out prior to data collection.

All testing was completed in a sound treated environment.

4.4 Procedure

1 Baseline susceptance and conductance values in the uncontracted state were obtained from simultaneously recorded susceptance and conductance tympanograms obtained using a 1000 Hz probe frequency. The pressure sweep for the tympanograms was in a positive to negative direction, pressure was varied at a rate of 50 daPa per second, between +200 and -300 daPa. The baseline susceptance and conductance values were recorded from the tympanometric peak pressures for each component. For notched tympanograms the central extremum was used for quantification. The recording of susceptance and conductance values at tympanometric peak was selected in preference to ambient pressure due to this being a more stable measure (Wilson, Shanks and Kaplan, 1984) and because the

reflex was automatically recorded at tympanometric peak pressure. A decrease in pressure (change in pressure from positive to negative) at a low rate was used as these conditions yield less complex tympanometric configurations (Margolis et al, 1985).

2 Reflex growth functions were obtained at the 1000 Hz probe frequency using identical procedures as were described for part one of the study (see chapter 2). The amount of mmho change at each intensity level was recorded. The same procedural considerations presented in chapter 2, in terms of the intensity range and reflex eliciting stimuli were made for part two of the study.

3 Baseline function was altered when diphasic reflexes were observed in order to determine whether diphasic patterns were dependent on baseline function. This was achieved by introducing a positive pressure (+200 daPa) to the external auditory meatus. The introduction of positive pressure serves to stiffen the system and results in different baseline functioning to that seen at peak tympanometric pressure, particularly at higher probe frequencies (Creten et al, 1978; Margolis and Popelka, 1977). The reflex was then elicited again, keeping the intensity of the reflex eliciting stimulus constant. The magnitude and direction of the reflex was again recorded.

4 The pattern of susceptance and conductance change caused by the reflex was established at each individual's resonant frequency. Feldman and Williams (1976) established the direction of susceptance and conductance change at 220 and 660 Hz probe frequencies using a tympanometric approach. As equipment limitations prevented recording of reflex induced admittance change measured against probe frequencies other than 226, 678 or 1000 Hz, a modified version of the Feldman and Williams procedure was used to determine the direction of susceptance and conductance change at resonance: Successive tympanometric runs without and with the acoustic reflex were made at each subjects resonant frequency. Resonant frequency was determined for each subject using the same procedure as was used in the first part of the study. The mmho value at the tympanometric peak was recorded for both the susceptance and conductance tympanograms at resonance. For notched tympanograms the central extremum was used for quantification. A 1000 Hz narrow band noise stimulus at an intensity of 98 dB SPL was then presented to the contralateral ear. While the stimulus was being presented, susceptance and conductance tympanograms were again recorded. The tympanometric peak was again identified as an indication of the susceptance and conductance values in the contracted state.

Contralateral recordings of the effect of the reflex at resonance were therefore made, as opposed to ipsilateral recordings for all other data collected in the present study. However, the probe ear remained the same throughout. Patterns of admittance change reported in part one of the study, recorded ipsilaterally, were similar to those reported previously in the literature for contralateral, simultaneous recordings. As the purpose of the identification of admittance change at resonance was to clarify direction, rather than magnitude, it was considered that contralateral recordings would not introduce additional variables which were unaccounted for.

Wilson et al (1984) state that procedures using successive tympanometric runs require careful interpretation as repeated introductions of variable pressure in the external auditory meatus results in the loosening of the transmission system of the middle ear which leads to increasingly complex tympanometric configurations and larger magnitudes. These researchers reported that where notched tympanograms were recorded, increases in complexity were characterised by a deepening of the notch. These researchers did find that changes in peak susceptance and conductance values of between 15 and 30 % occurred with successive tympanometric runs, but that after 3 - 5 runs no further increase in magnitude or complexity occurred. Creten et al (1985) and Decraemer, Creten and Van Camp (1984) avoided the effect of successive tympanometric runs from influencing results by varying the direction of the pressure change.

The pressure direction was kept constant (positive to negative) in the present study to avoid complex tympanometric configurations, as mentioned above. However, the admittance change due to the reflex recorded at resonance was always measured after at least three tympanometric runs had been completed (admittance recordings at a 226 Hz probe frequency) and susceptance and conductance tympanograms at resonance, as part of determining each individual's resonant frequency. Therefore it was expected that changes in tympanometric magnitude or shape would not be due to successive tympanometric runs, but rather due to the effect of the acoustic reflex.

4.5 Analysis Of The Data

4.5.1 Classification of ears into groups

Ears used in the present investigation were classified according to the tympanometric shape and the susceptance and conductance values at tympanometric peak pressure for the 1000 Hz probe frequency. This was done so that reflex patterns recorded using this probe frequency could be examined both within groups, for ears having similar baseline transmission properties and across groups having different baseline properties. The classification of tympanometric shape was made according the the Vanhuyse model (Vanhuyse et al, 1975). Ears with identical tympanometric configurations were grouped together. In addition, the tympanograms were quantified on the basis of the value at tympanometric peak to differentiate between ears demonstrating positive and negative susceptance values with notched tympanograms.

The results obtained for the 1000 Hz probe frequency were analysed within each of the groups as suggested by Sprague et al (1981) and Greenfield et al (1985) as wide variability across subjects is reported when similar patterns are not grouped together first. This was considered important as trends in the data may obscure individual findings (Block and Wiley, 1986).

4.5.2 Classification of admittance patterns at threshold and suprathreshold levels

The type of reflex pattern was classified as an increase or decrease (+ or -) in susceptance and increase or decrease (+ or -) in conductance, for each intensity level. The distribution of reflex patterns at threshold and where direction changes at suprathreshold levels occurred, was recorded for each group of ears.

Threshold was defined as the intensity level at which both of the components demonstrated reflexes which met the GSI criterion of 0.09 mmho for the 1000 Hz probe frequency.

4.5.3 Relationship between susceptance and conductance reflex patterns and reactance and resistance at the 1000 Hz probe frequency

Due to the equipment used, all reflex measurements were made conventionally, whereby baseline conditions were zeroed, and changes in susceptance and conductance were recorded as increases or decreases, recorded in mmho. In order to obtain absolute values of susceptance and conductance in the baseline condition, susceptance and conductance values were taken from the tympanometric peaks of the 1000 Hz tympanograms. Susceptance and conductance values recorded during the reflex were added to these baseline measures to provide absolute values for susceptance and conductance during the activation of the reflex at each stimulus frequency.

This information was presented in the form of three phasor diagrams for each subject representing each of the stimulus frequencies used in the study. The conductance value was presented on the X axis and the susceptance value on the Y axis, as described by Shanks, Lilly, Margolis, Wiley and Wilson (1988). The phasor trajectory was obtained by joining up the coordinates for each intensity level used. The resulting phasor diagrams were examined for:

1 Circular shape to represent a constant resistance (resistance being represented by the radius of the circle). The phasor trajectory for a simple mass - spring - damper system is described by Lutman (1984) as pasing through the origin with it's centre on the positive real axis.

2 Anticlockwise movement along the circumference of the circle to indicate an increase in stiffness during the activation of the acoustic reflex.

The phasor plots were analysed qualitatively as the information of interest was whether ears with different transmission properties all yield similar effects (namely an increase in stiffness), rather than quantifying this effect, which was beyond the scope of the present investigation. Quantitative analysis through summary statistics may have obscured the patterns obtained as different baseline transmission properties were expected across subjects for the 1000 Hz probe frequency.

4.5.4 Diphasic reflex patterns

The number of diphasic susceptance and conductance reflex patterns observed in each of the groups of ears was recorded. The effect of adding +200 daPa of pressure to the external auditory meatus was quantified by recording the direction, magnitude and shape of reflex patterns under these conditions. Summary statistics were used to show the central tendencies in terms of what effect the added stiffness had on the nature of the reflex patterns.

4.5.5 The direction of susceptance and conductance reflexes at each individual's resonant frequency

Summary statistics were used to describe central tendencies of baseline and reflex activated susceptance and conductance values obtained from the tympanomteric peak. As each ear was at resonance, transmission properties were considered to be similar enough across subjects so that measures of central tendency would not obscure patterns.

All summary statistics procedures and phasor diagrams were obtained using LOTUS 123, Copywrite (C), 1985, Lotus Development Corporation, Release 2.

CHAPTER 5
RESULTS AND DISCUSSION: PART TWO

5.1 Classification Of Ears Into Groups

The ears were divided into five different groups on the basis of transmission properties at 1000 Hz as indicated by tympanometric shape and susceptance and conductance values at tympanometric peak (see Table 16). The subjects assigned to each group are presented in Appendix D.

Table 16: Classification of ears used in the study into groups based on tympanometric shape and susceptance (B) and conductance (G) values at tympanometric peak pressure for the 1000 Hz probe frequency

Group 1 (n=9 ears)	Type 1 tympanograms (1B1G). All tympanometric peak B values larger than tympanometric peak G values, and all B values positive. Mean resonant frequency for this group was 1200 Hz
Group 2 (n=4 ears)	Type 2 tympanograms (3B1G). All tympanometric peak B values were larger than G values and all B values were positive. That is, susceptance tympanograms were notched, but the minimum value was still larger than the conductance value. Mean resonant frequency for this group was 1062 Hz
Group 3 (n=6 ears)	Type 2 tympanograms (3B1G) All tympanometric peak B values were smaller than tympanometric G values and all B values were positive. Mean resonant frequency for this group was 950 Hz
Group 4 (n=7 ears)	Type 3 tympanograms (3B3G). All tympanometric peak B values were smaller than tympanometric G values and all B values were positive. Mean resonant frequency for this group was 707 Hz
Group 5 (n=4 ears)	Type 3 tympanograms (3B3G). All tympanometric peak B values were negative. With the exception of one case, B values were smaller in absolute value than G values. Mean resonant frequency for this group was 650 Hz

5.2 Admittance Patterns At Threshold And Suprathreshold Levels

The distribution of reflex patterns across the groups at threshold shown in Table 17, indicates that as baseline transmission approaches, reaches and moves above resonance, there is a progression from -B+G to +B+G to -B+G to -B-G. This is a wider range of patterns than was seen at threshold in the first part of this study. This may have been due the use of only one ear from each subject which provided a wider range of baseline transmission characteristics at this probe frequency, as suggested by, for example, Creten et al (1985). As was found for the first part of the study, the suprathreshold reflex patterns were sometimes seen to differ from those at threshold, described as direction changes with increases in stimulus intensity. The patterns seen in the direction changes in this part of the study (Table 17) show that the direction of the reflex at suprathreshold intensity levels becomes identical to that commonly seen at threshold for a slightly more stiff middle ear system. As with the threshold reflex patterns, more variations in suprathreshold reflex patterns were seen than occurred for the first part of the study. This was obviously related to the wider range of reflex threshold patterns observed.

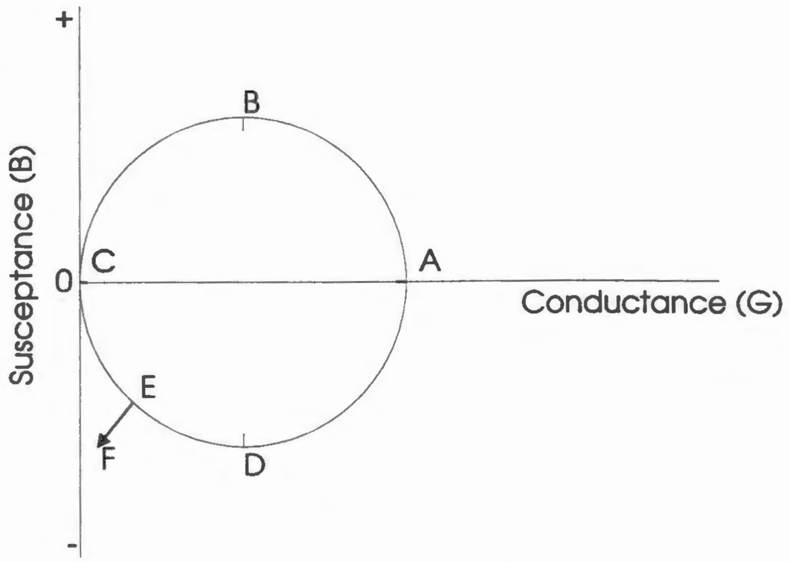
Table 17: **Susceptance and conductance reflex patterns at threshold and suprathreshold levels for each group, recorded for three stimuli at 1000 Hz probe frequency**

Where the direction of the reflex pattern (B or G) changed at suprathreshold intensity levels relative to threshold reflex patterns, the threshold and suprathreshold patterns are named and separated by a semicolon					
Reflex patterns for admittance components	**Group 1** (n=27)	**Group 2** (n=12)	**Group 3** (n=18)	**Group 4** (n=21)	**Group 5** (n=12)
-B-G					5
-B-G;-B+G					
-B+G				1	2
-B+G;+B+G				2	4
+B+G	1		5	6	1
+B+G;+B-G	8	2	11	7	
+B-G	18	10	2	5	

5.3 Relationships Between Susceptance And Conductance Reflex Patterns And Reactance And Resistance At The 1000 Hz Probe Frequency

Phasor plots and accompanying tables showing the measured susceptance and conductance values at rest and at each intensity level of the reflex activating stimulus for each of the stimuli are presented in Appendix E. The classification of susceptance and conductance reflexes as increases or decreases and the occurrence of diphasic reflexes are also indicated on the accompanying tables in Appendix E.

The examination of the phasors and the accompanying classifications indicates that 85 of the 90 growth functions can be described as circular, with the trajectory moving in an anticlockwise direction. This suggests that the effect of the reflex is an increase in stiffness. For 82 of the 85 growth functions demonstrating these patterns, the phasor diagrams appear to be circular in shape, passing through the origin, suggesting a constant resistance, stiffness change model, similar to that presented by Lutman and Martin (1979) and Lutman (1984). Various portions of the circular arc are traversed by the phasor trajectories, which relate closely to the classification of susceptance and conductance reflex patterns at reflex threshold and suprathreshold levels. These growth functions are represented schematically in Figure 5 and discussed in more detail below.



Key

Point A	Represents the natural frequency (resonance) of the system
Trajectory A - B	Represents increases in susceptance and decreases in conductance (+B-G)
Trajectory B - C	Represents decreases in susceptance and decreases in conductance (-B-G)
Trajectory C - D	Represents decreases in susceptance and increases in conductance (-B+G)
Trajectory D - A	Represents increases in susceptance and decreases in conductance (+B+G)
Trajectory E - F	Represents decreases in susceptance and decreases in conductance (-B-G)

Figure 5: **Schematic representation of the phasor diagrams obtained.**

The eight growth functions classified as -B+G or -B+G; +B+G in Table 17, which fit with the constant resistance stiffness change model were obtained from subjects 4, 5 and 12. The mean resonant frequency for these subjects was 683 Hz and baseline transmission properties without the reflex indicated that susceptance was smaller than conductance and was negative for subjects 4 and 12, but positive for subject 5. The baseline values are represented in the region of point C in Figure 5, and the phasor trajectories move in a circular, anticlockwise direction towards point D and then towards point A as direction of the susceptance reflex changes as a course of reflex growth. It is possible to stretch the circumference of these phasor plots to imagine that the circumference passes through the origin. This indicates that the pattern of decrease in susceptance and increase in conductance, with a direction change to increased susceptance at higher stimulus intensities is consistent with the hypothesised increase in negative reactance with constant resistance.

The growth functions classified as +B+G or +B+G; +B-G in Table 17 all fit with the constant resistance, stiffness change model, with the exception of subject 7 (2 kHz stimulus). These circular patterns with trajectory movement in an anticlockwise direction were obtained from subjects 1, 2, 3, 6, 8, 11, 12, 13, 16, 17, 18, 23, 29, and 30. A total of 40 growth functions fitting this classification were obtained due to some subjects showing this pattern for all the stimulus frequencies and others for only some of the stimulus frequencies. These subjects had a mean resonant frequency of 912 Hz, ranging from 650 Hz to 1300 Hz. A wide range of baseline transmission properties were obtained for these subjects at the 1000 Hz probe frequency, which is to be expected given the wide range of resonant frequencies obtained. The reflex pattern of +B+G or +B+G; +B-G resulted from baseline properties where susceptance was either positive or negative, and either smaller or larger than conductance. However, the mean resonant frequency of the group of ears is close to the probe frequency of 1000 Hz and baseline transmission can be approximated to the portion of the circumference between points D and A in figure 5. The phasor trajectory then moved towards points A for the +B+G classification and then towards point B as the direction of the conductance reflexes changed to a decrease (+B-G). For subjects 26 and 29 the probe frequency was markedly below their resonant frequencies (resonance being 1200 and 1300 Hz respectively) and baseline transmission could be represented between points A and B on the circumference in figure 5. For these subjects, even though they did demonstrate increases in both susceptance and conductance, this was for a very small intensity range and the direction of the conductance reflexes rapidly changed to a decrease, the more typical pattern for ears where the probe frequency is below the resonant frequency recorded (see discussion below).

The 34 growth functions classified as +B-G, which fit with the constant resistance, stiffness change model were obtained from subjects 3, 6, 7, 8, 15, 16, 19, 20, 21, 22, 24, 25, 27, and 28. The mean resonant frequency for this group of ears was 1042 Hz, and ranged from 500 to 1200 Hz. For most of the ears (subjects 3, 7 and 8 excepted) the probe frequency was below the resonant frequency and baseline transmission was represented between points A and B in figure 5. Movement along the trajectory was in a circular, anticlockwise direction, towards point B indicating an increase in stiffness and constant resistance being the result of the activation of the reflex, as hypothesised.

The 82 growth functions discussed above support the hypothesis that the effect of the reflex can be compared to a model of constant resistance and increased stiffness.

It is interesting to note that the plotting of the reflex growth functions as phasors illustrates how the apparent saturation of either the susceptance or conductance reflex growth functions is not saturation per se, but further increases in negative reactance with the trajectory curving in a circular arc. Lutman and Martin (1977) found little evidence of saturation in reflex growth functions when changes in susceptance and conductance were considered together. This finding is consistent with the display of results as phasor diagrams in the present study, and clarifies the suggestion in part one of this study that differentiation between growth functions type 2 and 3, as defined in chapter 3, is more of a quantitative than qualitative differentiation. Subject 10 in Appendix E illustrates how apparent saturation of the conductance reflex growth functions (for the 0.5 and 1 kHz stimuli) is represented as further increases in stiffness when results are considered together with susceptance growth functions and displayed as phasor plots.

Three growth functions were classified as -B-G, which could be related to an increase in stiffness, but for which the circular arc can not be seen to pass through the origin and the circular portion is difficult to relate to a constant resistance model. These three growth functions were all obtained from subject 14, who had a resonant frequency of 750 Hz and for whom baseline transmission indicated negative (mass dominated) susceptance values, which are represented by point E on the circumference of figure 5. The movement of the trajectory, appeared to be anti-clockwise, towards point F in figure 5. This pattern for a mass dominated system suggests an increase in negative reactance, but there may be an additional effect of the reflex on resistance as the trajectory is slightly different in shape to the theoretical model.

Five other growth functions presented as phasor plots did not fit with the constant resistance, stiffness change model. These were obtained from subjects 7 (1 kHz stimulus), 9 (0.5, 1 and 2 kHz stimuli) and 11 (2 kHz stimulus). These subjects have a mean resonant frequency of 550 Hz, and thus the probe frequency was above resonance. The phasor trajectory for subject 7 (1 kHz) appears to travel in a clockwise direction. Clockwise movement along the trajectory is suggestive of a decrease in stiffness (Lutman and Martin, 1979) although no circular arc is evident in the phasor plot and it is not clear whether this form of analysis is appropriate. The phasors obtained from subject 9 were also difficult to match to a circular arc, but were possibly influenced by a large number of diphasic reflexes, for whom the centre point was used to plot the phasors and this may in some way have obscured the pattern. Subject 11 appears to have an approximation of a circular arc, suggesting that resistance may be held constant, but the effect of the reflex appears to be a decrease, rather than the usual increase in stiffness.

These few exceptions to the general patterns of phasor plots which are consistent with a constant resistance, stiffness change model present some interesting possibilities. The subjects from whom these growth functions were obtained tended to have resonance frequencies below the probe frequency, indicating more influence from the mass in the system than the ears for whom resonance was above the probe frequency. This may indicate that for conditions where resonance is below the probe frequency, the simple increase in negative reactance may not be the result of the activation of the reflex. However, there were also ears for whom resonance was below the probe frequency and for whom the phasor plots matched the constant resistance, stiffness change model. This aspect of research could be extended to include an examination of the effect of the reflex at higher probe frequencies. Of particular interest would be the possible effect of the reflex on resistance, which is accepted to be constant for frequencies between 200 and 1500 Hz only (Van Camp, 1985). This may clarify the issue of the change in resistance caused by the reflex, and may add to explanations of the effect of the reflex on transmission properties of the middle ear which differentiate between the effect on low frequency and high frequency sound transmission (for example Lutman and Martin, 1979). Further research should, however consider the additional factors which may have influenced the results obtained in the present study. These factors include the question of nonsimultaneous as opposed to simultaneous measures of susceptance and conductance reflexes, and considering the effect of ear canal volume by correcting measures to the plane of the tympanic membrane. Such an investigation would extend beyond the scope of the present study, which was primarily concerned with acoustic reflexes are they are recorded in most conventional, clinical settings. The results obtained from the present investigation are however, encouraging from the clinical perspective as the recording of nonsimultaneous measures at the probe tip (such as is conventional in the clinical setting) have yielded results which are, in general, comparable to theoretical models of the effect of the acoustic reflex.

5.4 Diphasic Reflex Patterns

5.4.1 Distribution of diphasic susceptance and conductance reflex patterns

Thirty six diphasic reflex patterns were recorded for the subjects in part two of the study. These are presented in Appendix F. Because diphasic patterns are related to underlying resistance and reactance values, and Van Camp et al (1975) have shown that they are more likely to occur for higher probe frequencies, the distribution across the ears in the present study, in terms of the resistance/reactance relationships in the baseline condition is of interest. All diphasic susceptance patterns were recorded from ears which were mass dominated (see Table 18), which is consistent with the literature. However, there were also many instances of mass domination in which monophasic susceptance patterns were recorded.

Table 18: **Distribution of diphasic susceptance (B) patterns across groups. The direction of both admittance components is provided in the table**

	+B+G pattern Diphasic B	-B+G pattern Diphasic B	-B-G pattern Diphasic B
Group 1	0	0	0
Group 2	0	0	0
Group 3	0	0	0
Group 4	0	0	0
Group 5	2	2	4

Thus the results from the present study do not provide a clear indication of when diphasic susceptance patterns are to be expected. Diphasic conductance patterns were recorded across a wide range of ears with different baseline conditions (see Table 19). Creten et al (1976) found that diphasic conductance patterns only occurred where tympanograms were notched, that is they could not occur for ears for whom tympanograms were of the type 1B1G at the measuring probe frequency.

Table 19: **Distribution of diphasic conductance (G) patterns across groups. The direction of both admittance components is provided in the table**

	+B+G pattern Diphasic G	+B-G pattern Diphasic G	-B+G pattern Diphasic G
Group 1	4	1	0
Group 2	0	0	0
Group 3	6	5	0
Group 4	4	4	0
Group 5	0	0	4

In the present study there were a few diphasic conductance patterns recorded for ears which were stiffness dominated. However, a large portion of the diphasic conductance patterns were elicited from ears for whom the probe frequency was close to resonance suggesting that many of the diphasic conductance patterns occurred under the conditions suggested by Creten et al (1976).

There were more diphasic patterns observed at this probe frequency for the first part of the study, even though fewer ears were used and from a much smaller pool of individuals. This may have been related to the use of two ears from the same individual in several cases in part one, and only one ear from each individual in part two, suggesting perhaps that the likelihood of diphasic reflexes may be related to individual characteristics not identified in the present study. Another possible explanation for the discrepancy between the occurrences of diphasic reflexes in part one and two may be that diphasic patterns (which did tend to occur over a narrow intensity range and often in association with direction changes, see part one) may have been obscured in some ears because of the 4 dB increment size. As shown in Figure 6, direction changes were identified either with or without diphasic patterns in the present study. It is not clear whether all normal ears demonstrate diphasic reflex patterns in association

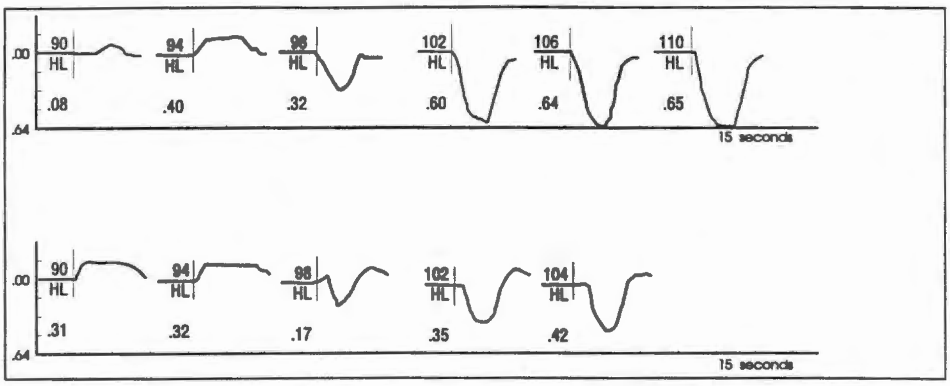


Figure 6: **Examples of direction changes not associated with diphasic reflexes (top row) and associated with diphasic reflexes (bottom row)**

with direction changes, and, whether, as questioned in part one, all occurrences of diphasic patterns are associated with the direction change phenomenon. Such an investigation, using subjects with wide dynamic ranges, and smaller step sizes may clarify this issue, which is beyond the scope of the present study.

5.4.2 Effect of introducing positive pressure into the external auditory meatus on reflex patterns

All diphasic reflex patterns became monophasic with the introduction of positive pressure into the external auditory meatus. An example of this is shown in Figure 7.

In addition to altering the morphology, the direction of the central portion of the reflex also changed with the addition of negative reactance. Under these conditions, all susceptance reflex patterns became positive, and all conductance patterns became negative. The results of this are also presented in Appendix F. This finding suggests that adding +200 daPa approximates the

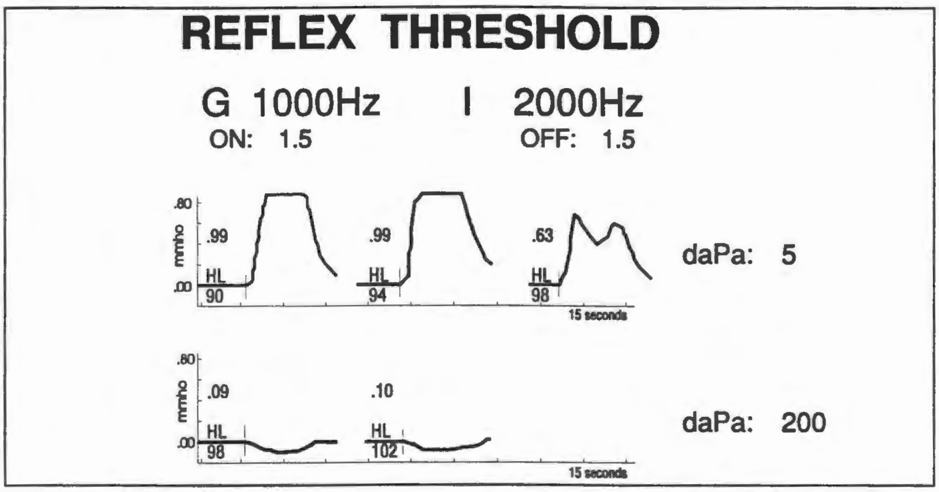


Figure 7: **Example of a diphasic conductance reflex pattern (top row) which became monophasic and (bottom row) with +200 daPa pressure variation in the external auditory meatus.**

transmission characteristics usually seen below resonance, in the region of 660 Hz, as is shown by the summary statistics in Table 20.

Table 20: Summary statistics to show the direction & magnitude of the monophasic changes which were obtained under conditions of positive pressure in the external auditory meatus

	Mean	Maximum	Minimum	Std Deviation
B	0.05	0.15	0.02	0.04
G	-0.09	-0.20	-0.03	0.04

This investigation indicates as hypothesised, that diphasic patterns recorded at higher probe frequencies in normal ears can be changed to monophasic changes by adding stiffness to the baseline conditions. These changes from diphasic to monophasic changes are also consistent with reports in the literature (for example Creten et al, 1976; Bennett and Weatherby, 1979).

5.5 The Direction Of Susceptance And Conductance Reflexes At Each Individual's Resonant Frequency

The resonant frequencies estimated for the 30 subjects and the effect of the reflex on susceptance and conductance at resonance (all subjects tested except for subject 5) are presented in Appendix G. It is apparent from this appendix that for some subjects (6, 19, 21, 22, 26, 27, 28 and 29) the conductance values were smaller than the susceptance values and this suggests that the natural frequency used to estimate resonance was not accurately identified. This may have related to the 50 Hz interval available on the GSI 33 multiple frequency tympanometry programme which restricted the accuracy with which the natural frequency could be identified to within 50 Hz. At each individual's resonant frequency, the +B+G pattern was recorded using the successive tympanometry procedure as shown in Table 21. In the previous explanation of phasor plots, the increase in susceptance and conductance (+B+G) was found for ears where the probe frequency was close to resonance and was consistent with a constant resistance, stiffness change model. The pattern is similar here, even though the methodology of obtaining reflex patterns (tympanometric approach as opposed to conventional recordings) was so different. Examples of susceptance and conductance tympanograms with and without the reflex activated are presented in Figure 8.

Table 21: Summary statistics to show the pattern of baseline and reflex activated susceptance and conductance measured at the probe tip at each individual's resonant frequency

	Mean	Minimum	Maximum	SD
B (baseline)	3.62	0.25	7.51	1.83
G (baseline)	5.23	2.64	10.89	1.68
B (reflex active)	4.11	0.8	7.78	1.79
G (reflex active)	5.65	2.73	11.74	1.87

The effect of the reflex as being an increase in negative reactance is shown by the shape of the susceptance tympanograms which shifted to more simple configurations with the reflex active.

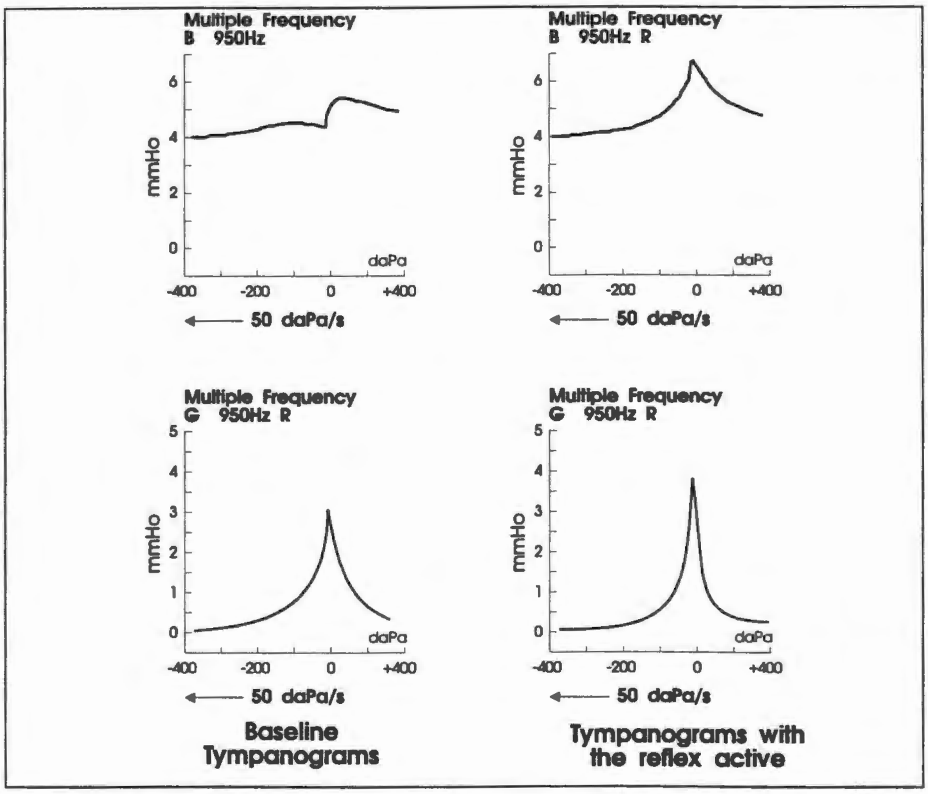


Figure 8: Examples of susceptance and conductance tympanograms with and without the acoustic reflex at resonance

In summary, the results from part two support the notion that underlying transmission properties at the specific probe frequency selected determine the direction of susceptance and conductance reflexes. Further, the results show that for most reflex growth functions recorded, the reflex classification is consistent with a constant resistance, stiffness change model. The occurrence of diphasic reflexes was also seen to relate closely to underlying resistance/reactance values. However, further research is required, which is aimed at explaining the effect of the reflex at the lateral surface of the tympanic membrane, rather than attempting to provide an expectation of reflex patterns as carried out in the clinical context. Such research may clarify the effect of the reflex for systems where the probe frequency is above resonance, in that it may establish whether the constant resistance model holds under such conditions.

CHAPTER 6
CONCLUSIONS

The effect of probe frequency and stimulus intensity on the magnitude, direction and morphology of susceptance and conductance reflex patterns measured at the probe tip using immittance procedures was clearly shown. In addition, the relationship between patterns of susceptance and conductance reflexes and increases in negative reactance during the reflex were demonstrated for the 1000 Hz probe frequency. This allows for more specific interpretations of reflex patterns obtained in conventional clinical investigations.

By knowing the transmission characteristics for a particular probe frequency, and the natural frequency (resonance) for the ear, the direction of measured susceptance and conductance reflexes and patterns of reflex growth can be compared to the normal pattern of increased negative reactance without having to either plot phasor diagrams or carry out simultaneous measures, neither of which is usually accessible in clinical investigations, or is economical in terms of time.

The continuum of reflex patterns from -B-G; +B-G; +B+G; -B+G along the circular arc of the phasor trajectory with increases in probe frequency, indicating an increase in negative reactance caused by the reflex can serve as a useful clinical guideline for judging whether reflexes recorded fit into a normal pattern or not.

Having established this continuum of susceptance and conductance reflex patterns in normal ears, it would now be possible to determine whether reflexes in research and clinical populations fit into or deviate from this pattern, provided that multiple frequency tympanometric measures were carried out together with the reflex measures to provide information of baseline conditions. It would be interesting to demonstrate the continuum of admittance reflex patterns across a range of probe frequencies in an individual ear. In addition, it would be interesting to establish reflex patterns in pathological ears, investigating whether specific pathologies (such as for example Meniere's Disease patients with large resistance components due to the retention of fluid in the cochlea) result in shifts along the normal continuum, or whether reflex patterns in pathological ears do not fit into the normal continuum at all. Such information would complement current knowledge of tympanometric configuration across frequencies.

Reflex morphology was also shown to be closely related to probe frequency. By changing baseline transmission properties through the introduction of positive pressure in the external auditory meatus, such patterns could always be changed to monophasic patterns. However, there remain several unanswered research questions as to when diphasic patterns emerge, particularly if there are individual ears which are more likely to yield these types of reflex patterns, and what differentiates these ears from others, or, whether diphasic patterns can always be recorded in normal ears given the correct procedural variables such as detailed measures with a very small increment size, or in individual's with wide dynamic ranges.

The effect of stimulus frequency on the direction, magnitude and the morphology of the reflex was not clearly shown in the present investigation. It would be interesting to investigate this aspect further with a wider range of stimulus frequencies, and possibly comparing ears with middle ear resonant frequencies which fall outside the normal range to determine how resonance and stimulus frequency interact. Further research in this area would help to clarify these issues.

The effect of the reflex on transmission characteristics of the middle ear were shown to be consistent with previous models of middle ear function. The value of immittance as a measuring technique for determining transmission characteristics was therefore again demonstrated. Particularly, the conventional method of measuring reflex related changes in susceptance and conductance at the probe tip was seen to compare fairly well with tympanometric approaches. Results obtained from both these forms of measurement could be related to theoretical explanations based on more complex immittance measures which record simultaneous susceptance and conductance reflexes and correct these to the plane of the tympanic membrane.

Further investigations of the effect of the acoustic reflex may be possible now that patterns of susceptance and conductance reflexes have been established. Such investigations might include recording changes in the admittance components along the frequency continuum in any single individual, and relating patterns to multiple frequency tympanometric measures. In addition, measures of other reflex related phenomena such as reflex latency and reflex decay, as indicators of retrocochlear auditory function may be possible now at higher probe frequencies, as normative patterns have been established for low and high intensity phenomena.

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REFERENCES

Bennett, M.J and Weatherby, L.A Multiple probe frequency acoustic reflex measurements. Scandinavian Audiology 8: 233 - 239, 1979.

Bennett, M.J and Weatherby, L.A Newborn acoustic reflexes to noise and pure-tone signals. Journal of Speech and Hearing Disorders 25, 383 - 387, 1982.

Berlin, C.I and Cullen, J.K The physical basis of impedance measurement. In Jerger,J and Northern, J (Eds) Clinical Impedance Audiometry (2nd Ed), American Electromedics Corp, 1980.

Block, M.G, and Wiley, T.L Acoustic-reflex growth for multitone complexes. Journal of Speech and Hearing Research 29: 92 - 98, 1986.

Brenkman, C.J; Grote, J.J. and Rutten, W.L.C. Acoustic transfer characteristics of human middle ears studied by a SQUID magnetometer method. Journal of the Acoustical Society of America. 82 (5) 1646 - 1654, 1987.

Colletti, V Multifrequency tympanometry. Audiology 16: 278 - 287, 1977.

Creten, W.L; Van Camp, K.J; Maes, M.A and Vanpeperstraete, P.M. The diagnostic value of phase angle tympanograms. Audiology 20: 1 - 14, 1981.

Creten, W.L, Van de Heyning, P.H and Van Camp, K.J Immittance audiometry: normative data at 220 and 660 Hz. Scandinavian Audiology 14: 115 - 121, 1985.

Creten, W.L, Vanpeperstraete, P.M and Van Camp, K.J Impedance and admittance tympanometry I: experimental approach. Audiology 17: 97 - 107, 1978.

Creten, W.L, Vanpeperstraete, P.M, Van Camp, K.J, and Doclo, J.R An experimental study on diphasic acoustic reflex patterns in normal ears. Scandinavian Audiology 5: 3 - 8, 1976.

Dallos, P.J Dynamics of the acoustic reflex: phenomenological aspects. Journal of the Acoustical Society of America 36 (11) 2175 - 2183, 1964.

Decraemer, W.F, Creten, W.L and Van Camp,K.J Tympanometric middle ear pressure determination with two-component admittance meters. Scandinavian Audiology 13: 165 - 172, 1984.

Djupesland, G The acoustic reflex. In Jerger, J and Northern, J (Eds) Clinical Impedance Audiometry (2nd Ed) American Electromedics Corp, 1980.

Djupesland,G and Kvernvold, H Acoustic impedance measured on ears with normal and diphasic impedance changes. Scandinavian Audiology 4: 39 - 43, 1975.

Elpern, B.S; Greisen, O. and Andersen, H.C. Experimental studies on sound transmission in the human ear: clinical and experimental observations on non-Otosclerotic ossicle fixation. Acta Oto-laryngologica 60: 223 - 329, 1965.

Feldman, A.S and Williams,P.S Tympanometric measurement of the transmission characteristics of the ear with and without the acoustic reflex. Scandinavian Audiology 5: 43 - 47, 1976.

Fitz-Gibbon, C.T. and Morris, L How to Analyze Data. Newbury Park, Sage, 1987.

Funasaka, S and Kumakawa, K Tympanometry using a sweep-frequency probe tone and its clinical evaluation. Audiology 27: 99 - 1008, 1988.

Funasaka, S; Funai, H and Kumakawa, K. Sweep frequency tympanometry: its development and diagnostic value. Audiology 23 (3) 366 - 379, 1984.

Funnell, W.R and Laszlo, C.A. A critical review of experimental observations on ear-drum structure and function. Otorhinolaryngology 44: 181 - 205, 1982.

Green, K.W and Margolis,R.H Detection of hearing loss with ipsilaterral acoustic reflex thresholds. Audiology 22: 471 - 479, 1983.

Greenfield, D.G; Wiley, T.L and Block, M.G Acoustic reflex dynamics and the loudness discomfort level. Journal of Speech and Hearing Disorders 50, 14 - 20, 1985.

Gundersen, T. and Hogmoen, K. Holographic vibration analysis of the ossicular chain. Acta Oto-laryngologica 82: 16 - 25, 1976.

Hall, J.W Effects of age and sex on static compliance. Archives of Otolaryngology 105: 153 - 156, 1979.

Hanks, W.D and Rose, K.J Middle ear resonance and acoustic immittance measures in children. Journal of Speech and Hearing Research 36: 218 - 222, 1993.

Hirsch, A The stapedius reflex tests in retrocochlear hearing disorders. Audiology 22: 463 - 470, 1983.

Holte, L; Margolis, R. H and Cavanaugh, R.M. Developmental changes in multifrequency tympanograms. Audiology 30 (1) 1 - 24, 1991.

Hung, I.J and Dallos, P Study of the acoustic reflex in human beings I: dynamic characteristics. Journal of the Acoustical Society of America 52 (4) Part 2, 1168 - 1180, 1972.

Jerger, J and Hayes, D Diagnostic applications of impedance audiometry. In Jerger, J and Northern, J (Eds) Clinical Impedance Audiometry (2nd Ed) American Electromedics Corp, 1980.

Kaplan, H, Gilman,S and Dirks,D.D Properties of acoustic reflex adaptation. Annals of Otology 86: 348 - 356, 1977

Kunov, H The "eardrum artifact" in ipsilateral acoustic reflex measurements. Scandinavian Audiology. 6, 163 - 166, 1977.

Laws, D.W and Moon, C.E Effects of the menstrual cycle on the human acoustic reflex threshold. Journal of Auditory Research 26: 197 - 206, 1986.

Lilly, D.L and Shanks, J.E Acoustic Immittance of an enclosed volume of air. In Popelka, G.R (Ed) Hearing Assessment with the Acoustic Reflex Grune and Stratton, 1981.

Lokberg, O.J.; Hogmoen, K. and Gundersen, T. Vibration measurement of the human tympanic membrane - in vivo. Acta Oto-laryngologica 89: 37 - 42, 1980.

Lutman, M.E Phasor Admitttance measurements of the middle ear I: theoretical aspects. Scandinavian Audiology 13: 253 - 264, 1984.

Lutman, M.E Personal communication. 1993.

Lutman, M.E and Leis,B.R Ipsilateral acoustic reflex artefacts measured in cadavers. Scandinavian Audiology 9: 33 - 39, 1980.

Lutman, M.E and Martin, A.M. Development of an electroacoustic analogue model of the middle ear and acoustic reflex. Journal of Sound and Vibration 64 (1) 133 - 157, 1979.

Lutman, M.E and Martin, A.M. The response of the acoustic reflex as a function of the intensity and temporal characteristics of pulsed stimuli. Journal of Sound and Vibration 54 (3) 345 - 360, 1977.

Lutman, M.E and Martin, A.M. The variablility of acoustic reflex threshold measurements. Journal of Sound and Vibration 48(3) 413 - 420, 1976.

Lutman, M.E, McKenzie, H and Swan, R.C Phasor admittance of the middle ear II: normal phasor tympanograms and acoustic reflexes. Scandinavian Audiology 13: 265 - 274, 1984.

Mangham, C.A, Burnett, P.A Lindeman, R.C Evaluation of tensor tympani muscle dominance in the biphasic acoustic reflex. Audiology 22: 105 - 119, 1983.

Margolis, R.H Fundamentals of acoustic immittance. In Popelka, G.R (Ed) Hearing Assessment with the Acoustic Reflex Grune and Stratton, 1981.

Margolis,R.H and Popelka, G.R Interaction among tympanometric variables. Journal of Speech and Hearing Research 20: 447 - 462, 1977.

Margolis,R.H, Van Camp, K.J, Wilson, R.H and Creten, W.L Multifrequency tympanometry in normal ears. Audiology 24: 44 - 53, 1985.

Miller, S Experimental design and statistics. Metheun, 1975.

Møller, A.R Acoustic reflex in man. Journal of the Acoustical Society of America 34 (8) Part 2, 1524 - 1534 1962.

Møller, A.R Auditory Physiology. Academic Press. 1983.

Møller, A.R Network model of the middle ear. Journal of the Acoustical Society of America 33 (2), 168 - 176, 1961.

Northern, J.L. Impedance measurements with distinctive groups. In Jerger, J. and Northern, J.L (Eds) Clinical impedance audiometry (2nd Ed) American Electromedics corporation, 1980.

Popelka, G.R Instrumentation and procedures for measuring acoustic-reflex thresholds. In Popelka, G.R (Ed) Hearing Assessment with the Acoustic Reflex Grune and Stratton, 1981.

Shanks, J.E, Lilly, D.J, Margolis, R.H, Wiley, T.L, and Wilson, R.H Tympanometry. Journal of Speech and Hearing Disorders 53 (4) 354 - 377, 1988.

Silman, S. The effects of aging on the stapedius reflex thresholds. Journal of the Acoustical Society of America 66 (3), 735 - 738, 1979.

Silman, S and Silverman, C.A. Auditory Diagnosis. Academic Press, London, 1991.

Silman, S, Popelka, G.R and Gelfand, S.A Effect of sensorineural hearing loss on acoustic stapedius reflex growth function. Journal of the Acoustical Society of America 64 (5) 1406 - 1411, 1978.

Sprague, B.H, Wiley,T.L and Block, M.G Dynamics of acoustic reflex growth. Audiology 20: 15 - 40, 1981.

Terkildsen,K, Osterhammel,P and Bretlau, P Acoustic middle ear muscle reflexes in patients with otosclerosis. Archives of Otolaryngology 98: 152 - 155, 1973.

Thompson, D.J, Sills, J.A, Recke, K.S and Bui, D.M Acoustic reflex growth in the aging adult. Journal of Speech and Hearing Research 23 405 - 418, 1980.

Updike, C.D and Epstein, A. Characteristics of the acoustic reflex in response to narrow bands of noise. Journal of Auditory Research 26: 147 - 156, 1986

Van Camp, K.J The Shape of meatus-compensated immittance loci. Scandinavian Audiology 14, 175 - 176, 1985.

Van Camp, K.J and Creten, W.L Principles of acoustic impedance and admittance. In Feldman, A.S and Wilbur, L.A (Eds) Acoustic Impedance and Admittance - the measurement of middle ear function Williams and Wilkins, 1976.

Van Camp, K.J and Vogeleer,M A Tympanometric approach to otosclerosis. Scandinavian Audiology 15: 109 - 114, 1986.

Van Camp, K.J, Creten, W.L, Van de Heyning,P.H, Decraemer, W.F and Vanpeperstraete, P.M A search for the most suitable immittance components and probe frequency in tympanometry. Scandinavian Audiology 12: 27 - 34, 1983.

Van Camp, K.J, Vanhuyse, V.J, Creten, W.L and Vanpeperstraete, P.M Impedance and admittance tympanometry II: mathematical approach. Audiology 17: 108 - 119, 1978.

Van Camp, K.J, Vanpeperstraete, P.M, Creten, W.L and Vanhuyse, V.J On irregular acoustic reflex patterns. Scandinavian Audiology 4: 227 - 232, 1975.

Vanhuyse, V.J, Creten, W.L and Van Camp, K.J On the W-notching of tympanograms. Scandinavian Audiology 4: 45 - 50, 1975.

Wada, H and Kobayashi, T Dynamical behaviour of middle ear: theoretical study corresponding to measurement results obtained by a newly developed measuring apparatus. Journal of the Acoustical Society of America 87 (1), 237 - 245, 1990.

Wada, H, Kobayishi, T, Suetake, M and Tachikazi, H Dynamic behaviour of the middle ear based on sweep frequency tympanometry. Audiology 28: 127 - 134, 1989.

Weatherby, L.A and Bennett, M.J. The neonatal acoustic reflex. Scandinavian Audiology 9:103 - 110, 1980.

Wiley, T.L and Block, M.G Static acoustic-immittance measurements. Journal of Speech and Hearing Research 22: 677 - 696, 1979.

Wiley, T.L and Block, M.G Overview and basic principles of acoustic immittance measurements. In Katz, J (Ed) Handbook of Clinical Audiology (3rd Ed) Williams and Wilkins, 1985.

Wilson, R.H, Shanks,J.E and Kaplan, S.K Tympanometric changes at 226 Hz and 678Hz across 10 trials for two directions of ear canal pressure change. Journal of Speech and Hearing Research 27: 257 - 266, 1984.

Wilson,R.H, and McBride,L.M Threshold and growth of the acoustic reflex. Journal of the Acoustical Society of America 63 (1) 147 - 164, 1978.

Yantis, P.A Puretone air-conduction testing. In Katz, J (Ed) Handbook of Clinical Audiology (3rd Ed) Williams and Wilkins, 1985.

Zwislocki, J Analysis of middle ear function Part 1: input impedance. Journal of the Acoustical Society of America 34 (2) 1514 - 1523, 1962.

APPENDIX A

Natural Frequencies used to Approximate Resonance, Recorded for the 19 Subjects in Part One.

NATURAL FREQUENCY USED AS AN ESTIMATE OF RESONANT FREQUENCY FOR SUBJECTS IN PART ONE

SUBJECT	RESONANT FREQUENCY IN Hz
1	1000
2	1000
3	1000
4	700
5	850
6	1000
7	800
8	950
9	850
10	1050
11	800
12	800
13	800
14	750
15	750
16	1000
17	1600
18	1000
19	850

APPENDIX B

Zeroed mmho Values Recorded for Subjects in Part One at 226, 678 and 1000 Hz Probe Frequencies for 0.5, 1 and 2 kHz Stimuli.

226 Hz PROBE FREQUENCY 0.5 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

				dBHL							
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	-0.01	-0.04	-0.09	-0.14	-0.23	-0.25	-0.26	-0.27	-0.26	-0.25
2	-0.16	-0.01	-0.01	-0.03	-0.08	-0.12	-0.21	-0.23	-0.24	-0.24	-0.23	-0.23
3	0.00	0.00	0.00	-0.03	-0.09	-0.16	-0.20	-0.24	-0.26	-0.27	-0.27	-0.27
4	0.00	0.01	0.01	-0.01	-0.05	-0.10	-0.15	-0.21	-0.26	-0.26	-0.28	-0.40
5	0.01	0.01	0.00	0.01	-0.01	0.01	-0.02	-0.06	-0.07	-0.09	-0.09	-0.10
6	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	-0.02	-0.03	-0.06	-0.07	-0.08	-0.09
7	0.00	0.00	0.00	-0.01	-0.02	-0.07	-0.13	-0.18	-0.19	-0.21	-0.22	-0.22
8	0.00	0.00	0.00	0.01	0.00	-0.06	-0.10	-0.14	-0.16	-0.17	-0.18	-0.18
9	-0.02	-0.03	-0.03	-0.50	-0.14	-0.11	0.25	-0.12	-0.13	-0.16	-0.12	-0.13
10	0.01	0.01	0.02	-0.01	-0.06	-0.10	-0.14	-0.18	-0.16	-0.17	-0.18	-0.16
11	0.01	0.00	0.00	0.00	0.00	-0.01	-0.02	-0.04	-0.09	-0.11	-0.13	-0.13
12	0.00	0.00	0.01	-0.04	-0.07	-0.11	-0.08	-0.10	-0.10	-0.12	-0.13	-0.13
13	-0.01	0.00	0.00	-0.03	-0.09	-0.13	-0.16	-0.17	-0.20	-0.22	-0.21	-0.21
14	0.01	0.01	0.00	-0.01	0.00	0.01	-0.04	-0.09	-0.15	-0.16	-0.18	-0.18
15	-0.01	0.00	0.04	0.00	0.00	-0.04	-0.16	-0.15	-0.19	-0.23	-0.24	-0.27
16	0.00	0.00	0.00	0.00	-0.02	-0.04	-0.08	-0.11	-0.14	-0.15	-0.17	-0.16
17	0.00	-0.01	-0.01	-0.02	-0.04	-0.05	-0.07	-0.08	-0.10	-0.12	-0.13	-0.12
18	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02	-0.03	-0.04	-0.04	-0.04
19	0.01	-0.01	-0.01	0.00	0.00	-0.01	-0.03	-0.05	-0.09	-0.11	-0.10	-0.09

226 Hz PROBE FREQUENCY 0.5 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

				dBHL							
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	-0.02	0.00	0.00	-0.06	-0.07	-0.10	-0.12	-0.13	-0.15	-0.13	-0.13	-0.13
2	0.00	0.00	-0.01	-0.04	-0.07	-0.10	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13
3	0.00	0.00	0.00	-0.05	-0.09	-0.14	-0.18	-0.19	-0.20	-0.18	-0.17	-0.15
4	0.01	0.01	0.02	0.01	-0.08	-0.15	-0.21	-0.22	-0.26	-0.25	-0.25	-0.25
5	0.00	0.00	0.00	0.00	0.01	-0.01	-0.03	-0.05	-0.05	-0.05	-0.06	-0.08
6	0.00	0.00	-0.01	0.01	0.00	0.00	-0.01	-0.02	-0.03	-0.02	-0.03	-0.02
7	-0.01	-0.01	0.01	-0.01	-0.02	-0.09	-0.24	-0.26	-0.28	-0.26	-0.27	-0.26
8	0.00	0.00	0.00	0.00	-0.05	-0.11	-0.15	-0.17	-0.19	-0.19	-0.20	-0.20
9	-0.02	-0.01	0.01	0.01	-0.07	-0.13	-0.12	-0.14	-0.14	-0.15	-0.15	-0.13
10	0.00	0.00	0.00	-0.01	-0.03	-0.06	-0.08	-0.08	-0.08	-0.10	-0.06	-0.07
11	0.00	-0.01	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.06	-0.06	-0.07	-0.07
12	-0.01	0.01	-0.01	0.01	-0.01	-0.02	-0.04	-0.05	-0.06	-0.05	-0.04	-0.04
13	-0.01	-0.01	0.01	-0.02	-0.03	-0.05	-0.07	-0.08	-0.09	-0.07	-0.08	-0.09
14	0.00	0.00	0.01	0.01	0.01	0.01	-0.01	-0.05	-0.02	-0.01	-0.05	-0.05
15	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	-0.09	-0.12	-0.13	-0.13	-0.13
16	-0.01	-0.01	-0.01	-0.02	-0.04	-0.06	-0.08	-0.09	-0.08	-0.09	-0.10	-0.09
17	0.00	-0.01	-0.01	-0.01	-0.03	-0.04	-0.05	-0.06	-0.05	-0.06	-0.06	-0.05
18	-0.01	0.00	-0.01	-0.01	0.00	0.00	0.00	-0.01	-0.02	-0.01	-0.02	-0.02
19	-0.01	0.00	0.00	0.00	0.00	-0.01	-0.03	-0.05	-0.05	-0.07	-0.07	-0.06

226 Hz PROBE FREQUENCY 1 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

					dBHL							
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.00	0.00	0.00	-0.05	-0.13	-0.17	-0.21	-0.25	-0.25	-0.24
2	-0.01	-0.01	-0.03	-0.03	-0.05	-0.11	-0.18	-0.20	-0.23	-0.24	-0.22	-0.23
3	-0.01	0.00	0.00	-0.01	-0.06	-0.15	-0.21	-0.25	-0.29	-0.30	-0.31	-0.31
4	0.00	0.00	0.00	0.00	-0.02	-0.09	-0.20	-0.22	-0.24	-0.29	-0.31	-0.32
5	0.01	0.00	0.00	0.00	0.00	-0.02	-0.03	-0.06	-0.11	-0.11	-0.13	-0.13
6	0.00	0.00	0.00	-0.01	0.00	0.00	-0.03	-0.05	-0.06	-0.07	-0.07	-0.08
7	0.01	0.00	0.01	-0.03	-0.04	-0.13	-0.18	-0.22	-0.23	-0.23	-0.24	-0.24
8	0.00	0.00	0.00	0.00	-0.01	-0.10	-0.12	-0.16	-0.16	-0.18	-0.18	-0.19
9	0.04	0.03	-0.02	0.04	-0.03	-0.05	-0.07	-0.13	-0.15	-0.15	-0.18	-0.15
10	-0.01	0.00	0.00	-0.01	-0.07	-0.11	-0.16	-0.18	-0.21	-0.18	-0.20	-0.21
11	0.01	-0.01	-0.01	0.01	0.00	0.00	-0.04	-0.06	-0.08	-0.10	-0.13	-0.13
12	0.00	0.00	-0.02	-0.04	-0.07	-0.11	-0.14	-0.16	-0.18	-0.19	-0.20	-0.20
13	0.01	0.01	-0.02	-0.06	-0.10	-0.14	-0.16	-0.18	-0.19	-0.19	-0.20	-0.21
14	0.00	-0.02	0.00	0.01	0.00	0.00	-0.01	-0.07	-0.12	-0.13	-0.14	-0.14
15	0.00	0.00	0.00	0.00	0.00	-0.01	-0.13	-0.19	-0.20	-0.23	-0.25	-0.26
16	0.00	-0.01	-0.01	-0.01	-0.03	-0.06	-0.09	-0.12	-0.12	-0.15	-0.15	-0.15
17	0.00	-0.01	-0.01	-0.04	-0.05	-0.07	-0.08	-0.09	-0.10	-0.11	-0.12	-0.12
18	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.03	-0.04	-0.05	-0.05
19	0.00	0.00	0.00	0.00	0.00	-0.01	-0.05	-0.06	-0.08	-0.10	-0.10	-0.12

226 Hz PROBE FREQUENCY 1 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

					dBHL							
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.00	0.00	0.00	-0.05	-0.07	-0.10	-0.12	-0.12	-0.11	-0.12
2	0.00	0.00	0.00	-0.02	-0.06	-0.08	-0.11	-0.12	-0.13	-0.12	-0.13	-0.12
3	0.00	0.00	-0.01	-0.01	-0.08	-0.14	-0.21	-0.21	-0.20	-0.20	-0.20	-0.20
4	0.01	-0.01	0.00	0.00	-0.08	-0.09	-0.15	-0.19	-0.20	-0.22	-0.21	-0.23
5	0.02	0.01	0.00	0.00	0.00	0.01	-0.03	-0.06	-0.07	-0.08	-0.08	-0.09
6	0.01	0.00	0.01	0.00	-0.01	-0.01	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03
7	0.00	0.00	0.00	-0.04	-0.15	-0.19	-0.26	-0.22	-0.23	-0.23	-0.23	-0.23
8	0.00	0.00	0.00	0.00	-0.09	-0.14	-0.17	-0.19	-0.19	-0.19	-0.19	-0.19
9	-0.02	0.02	0.02	0.03	-0.11	-0.15	-1.04	-0.43	-0.71	-1.11	-1.15	-0.87
10	0.00	0.00	0.00	-0.01	-0.07	-0.09	-0.10	-0.12	-0.12	-0.11	-0.11	-0.11
11	0.00	0.00	0.01	0.01	0.01	-0.01	-0.05	-0.04	-0.06	-0.07	-0.07	-0.06
12	0.00	0.00	0.00	-0.03	-0.04	-0.07	-0.07	-0.09	-0.11	-0.10	-0.10	-0.10
13	0.01	0.01	-0.01	-0.04	-0.04	-0.06	-0.08	-0.09	-0.08	-0.10	-0.09	-0.08
14	0.00	-0.01	0.00	0.00	-0.02	-0.01	-0.02	-0.07	-0.08	-0.08	-0.09	-0.08
15	0.00	0.01	0.01	0.01	0.01	0.01	-0.07	-0.11	-0.12	-0.13	-0.13	-0.14
16	-0.01	-0.01	0.00	-0.01	-0.03	-0.06	-0.09	-0.09	-0.09	-0.09	-0.10	-0.10
17	-0.01	-0.01	-0.01	-0.03	-0.03	-0.04	-0.06	-0.06	-0.06	-0.05	-0.06	-0.06
18	0.00	-0.01	-0.01	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
19	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.04	-0.04	-0.06	-0.06	-0.07	-0.07

226 Hz PROBE FREQUENCY   2 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL									
Ss	66	70	74	78	82	86	90	94	98	102	104
1	0.00	0.00	0.00	0.00	0.00	-0.02	-0.07	-0.12	-0.19	-0.19	-0.22
2	0.00	0.00	0.00	0.00	-0.01	-0.06	-0.10	-0.15	-0.18	-0.20	-0.22
3	0.00	0.00	0.00	0.00	-0.02	-0.03	-0.09	-0.21	-0.26	-0.26	-0.27
4	0.00	0.00	0.00	0.00	0.00	-0.01	-0.04	-0.07	-0.20	-0.26	-0.29
5	-0.01	-0.01	0.00	0.00	-0.01	-0.01	-0.06	-0.11	-0.13	-0.14	-0.13
6	-0.01	0.00	0.00	0.00	-0.01	0.00	-0.02	-0.06	-0.09	-0.09	-0.09
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	-0.12	-0.19	-0.19
8	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.10	-0.11	-0.16	-0.15
9	0.04	-0.05	-0.04	-0.04	-0.02	-0.01	-0.08	-0.17	-0.09	-0.06	-0.04
10	0.00	0.00	0.00	0.03	0.00	-0.03	-0.11	-0.18	-0.19	-0.18	-0.21
11	0.00	0.01	0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.04	-0.07	-0.06
12	0.00	0.00	0.00	0.00	0.00	-0.02	-0.04	-0.07	-0.07	-0.11	-0.14
13	0.01	0.00	-0.01	0.00	-0.01	-0.01	-0.02	-0.03	-0.09	-0.10	-0.13
14	-0.03	0.02	0.03	0.04	0.01	-0.06	-0.15	-0.23	-0.24	-0.23	-0.24
15	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.07	-0.16	-0.23	-0.25
16	0.01	0.00	-0.01	-0.02	-0.06	-0.09	-0.12	-0.14	-0.13	-0.15	-0.16
17	0.00	0.00	-0.01	0.00	-0.01	-0.04	-0.06	-0.07	-0.10	-0.12	-0.15
18	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.02	-0.03	-0.03
19	0.00	-0.01	0.00	-0.01	0.00	0.00	-0.02	-0.04	-0.04	-0.08	-0.09

226 Hz PROBE FREQUENCY   2 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL									
Ss	66	70	74	78	82	86	90	94	98	102	104
1	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	-0.10	-0.10	-0.11	-0.11
2	0.00	0.00	0.00	0.00	-0.04	-0.08	-0.09	-0.10	-0.14	-0.13	-0.13
3	0.00	0.00	0.00	0.01	-0.01	-0.08	-0.14	-0.18	-0.19	-0.19	-0.19
4	0.01	0.01	0.00	-0.01	0.02	-0.01	-0.04	-0.08	-0.13	-0.18	-0.20
5	-0.01	-0.01	0.00	0.00	0.00	-0.01	-0.07	-0.08	-0.09	-0.09	-0.09
6	-0.01	0.00	0.01	-0.01	0.01	0.01	-0.02	-0.03	-0.04	-0.04	-0.03
7	0.01	-0.01	0.00	0.00	0.00	-0.02	-0.05	-0.11	-0.17	-0.22	-0.22
8	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	-0.11	-0.17	-0.17	-0.19
9	0.01	0.01	0.02	0.02	0.01	-0.15	-0.16	-0.14	-0.20	-0.19	-0.14
10	0.00	0.00	0.00	-0.01	0.02	-0.03	-0.09	-0.11	-0.12	-0.11	-0.12
11	0.01	0.00	-0.01	-0.01	0.00	0.01	-0.01	-0.02	-0.03	-0.02	-0.05
12	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02	-0.03	-0.05	-0.08	-0.09
13	0.00	0.00	0.01	-0.01	-0.01	-0.01	-0.03	-0.05	-0.05	-0.07	-0.07
14	-0.02	0.00	0.01	0.02	-0.01	0.00	-0.04	-0.05	-0.42	-0.81	-1.01
15	0.00	0.00	0.00	0.00	0.00	-0.02	-0.07	-0.11	-0.10	-0.09	-0.11
16	-0.01	-0.01	0.00	-0.03	-0.04	-0.07	-0.09	-0.09	-0.09	-0.09	-0.09
17	0.00	0.00	0.00	0.00	-0.01	-0.02	-0.04	-0.04	-0.04	-0.05	-0.06
18	0.01	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	-0.02	-0.02
19	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.03	-0.03	-0.05	-0.04

678 Hz PROBE FREQUENCY 0.5 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL										
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.00	0.00	0.00	0.06	0.24	0.42	0.59	0.43	0.36	0.35
2	0.00	0.00	0.00	0.00	0.02	0.12	0.22	0.50	0.57	0.40	0.35	0.40
3	0.00	0.03	0.04	0.10	0.42	0.45	0.63	0.59	0.44	0.39	0.32	0.29
4	0.02	0.02	0.04	0.13	0.60	0.91	1.07	0.94	0.77	0.67	0.55	0.51
5	0.01	0.03	-0.02	0.00	-0.03	-0.01	0.12	0.30	0.33	0.28	0.21	0.22
6	0.00	0.00	-0.02	0.00	0.00	0.00	0.01	0.08	0.15	0.15	0.08	0.08
7	-0.01	0.01	0.00	0.04	0.06	0.30	0.43	0.35	0.34	0.29	0.27	0.27
8	0.00	0.01	0.00	0.00	0.01	0.14	0.35	0.29	0.34	0.27	0.28	0.20
9	0.39	0.38	0.27	0.30	0.33	0.24	0.47	0.10	0.31	0.27	0.14	0.24
10	-0.03	0.00	0.00	-0.12	0.11	0.58	1.05	1.25	1.44	1.33	1.35	1.28
11	-0.06	-0.03	-0.03	-0.07	0.02	0.00	-0.01	0.10	0.18	0.20	0.20	0.13
12	0.00	0.00	0.05	0.09	0.19	0.32	0.43	0.37	0.24	0.21	0.16	-0.01
13	0.01	0.02	0.17	0.27	0.38	0.62	0.65	0.51	0.41	0.36	0.28	0.22
14	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.52	0.83	0.72	0.67	0.57
15	0.02	0.02	-0.01	0.01	0.00	-0.02	0.01	0.01	0.35	0.56	0.44	0.33
16	0.00	0.00	0.00	0.01	0.01	0.02	0.14	0.23	0.22	0.15	0.09	0.13
17	0.00	0.00	0.00	-0.01	0.00	0.00	0.02	0.04	0.00	-0.05	-0.08	-0.11
18	-0.01	-0.01	0.00	0.00	-0.01	0.01	0.00	0.03	0.05	0.06	0.06	0.01
19	0.00	0.00	-0.03	-0.02	0.03	0.01	0.18	0.30	0.30	0.26	0.20	0.21

678 Hz PROBE FREQUENCY 0.5 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL										
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01	-0.13	-0.60	-1.02	-1.05	-1.04
2	0.00	0.00	0.00	0.00	0.00	0.00	-0.19	-0.86	-0.95	-0.91	-0.91	-0.91
3	0.00	0.02	0.02	0.04	0.04	-0.07	-0.56	-0.88	-1.25	-1.29	-1.30	-1.33
4	-0.03	0.01	0.01	-0.02	-0.18	-0.56	-1.61	-2.17	-2.38	-2.64	-2.67	-2.58
5	-0.02	-0.01	0.00	-0.01	-0.02	0.00	-0.01	-0.05	-0.33	-0.42	-0.52	-0.68
6	-0.01	0.00	0.00	0.00	-0.01	0.00	-0.01	-0.06	-0.22	-0.39	-0.59	-0.57
7	0.00	0.00	-0.01	0.00	0.02	-0.07	-0.41	-0.68	-0.81	-0.88	-0.90	-0.90
8	0.00	0.00	0.00	0.00	0.02	0.07	-0.13	-0.46	-0.61	-0.68	-0.71	-0.74
9	-0.10	-0.11	0.14	0.15	0.11	0.14	-0.10	-0.43	-0.32	-0.42	-0.62	-0.48
10	0.00	-0.01	0.01	0.05	0.30	0.44	0.37	-0.14	-0.46	-0.50	-0.66	-0.66
11	0.14	-0.09	-0.01	0.01	-0.01	0.01	-0.15	-0.03	-0.35	-0.54	-0.78	-0.83
12	0.00	0.00	-0.05	-0.10	-0.06	-0.34	-0.64	-0.98	-0.67	-1.24	-1.27	-1.29
13	0.00	0.02	0.00	0.00	-0.15	-0.40	-1.05	-1.32	-1.52	-1.58	-1.62	-1.65
14	-0.02	0.00	0.01	0.02	-0.01	0.00	-0.04	-0.05	-0.42	-0.81	-1.01	-1.05
15	0.00	0.01	-0.02	0.00	0.04	-0.02	0.00	0.00	-1.02	-0.53	-0.83	-1.02
16	0.00	0.01	0.00	0.00	0.00	-0.05	-0.10	-0.26	-0.48	-0.61	-0.69	-0.70
17	0.00	0.00	0.00	0.00	0.00	-0.04	-0.06	-0.18	-0.25	-0.38	-0.42	-0.51
18	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.09	-0.15	-0.30	-0.42	-0.42
19	0.00	0.00	0.00	-0.02	-0.02	0.00	-0.18	-0.36	-0.57	-0.66	-0.76	-0.71

678 Hz PROBE FREQUENCY 1 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL										
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.25	0.46	0.42	0.36	0.26
2	0.00	0.03	-0.02	0.00	0.00	0.06	0.40	0.52	0.54	0.39	0.37	0.35
3	0.02	0.00	0.00	0.01	0.03	0.53	0.74	0.70	0.46	0.45	0.41	0.36
4	-0.10	-0.04	-0.04	0.21	0.83	0.90	0.93	0.76	0.65	0.59	0.55	0.55
5	-0.05	0.01	0.00	0.02	0.00	-0.01	-0.03	0.11	0.37	0.30	0.23	0.24
6	-0.01	-0.01	0.01	-0.01	0.00	0.00	0.02	0.05	0.05	-0.02	-0.09	-0.12
7	-0.01	0.00	0.01	0.03	0.20	0.38	0.40	0.34	0.27	0.22	0.24	0.16
8	0.00	0.00	0.00	0.00	0.04	0.33	0.42	0.39	0.37	0.34	0.30	0.29
9	-0.02	0.01	0.04	0.02	0.02	0.11	0.23	0.18	0.15	0.16	0.15	0.17
10	-0.02	-0.03	0.09	0.21	0.24	0.22	0.23	0.15	0.15	0.16	0.09	0.09
11	0.02	0.00	-0.02	0.00	0.00	-0.02	0.02	0.10	0.20	0.22	0.23	0.19
12	0.00	0.00	0.00	0.01	0.09	0.26	0.29	0.33	0.24	0.12	0.16	0.07
13	0.00	0.00	0.02	0.20	0.47	0.57	0.51	0.44	0.40	0.36	0.33	0.23
14	0.00	0.05	0.00	0.02	0.00	0.00	0.18	0.44	0.32	0.24	0.15	0.16
15	0.00	-0.01	0.00	-0.04	0.03	0.00	0.02	0.32	0.53	0.48	0.40	0.25
16	0.00	0.00	0.00	0.00	0.00	0.08	0.29	0.33	0.32	0.26	0.23	0.20
17	0.00	-0.01	0.00	0.00	0.01	0.02	0.01	-0.03	-0.06	-0.09	-0.11	-0.15
18	0.00	0.01	0.01	0.02	0.00	0.00	0.06	0.12	0.11	0.15	0.12	0.10
19	0.00	0.00	-0.01	0.01	0.00	0.19	0.34	0.45	0.47	0.46	0.43	0.43

678 Hz PROBE FREQUENCY 1 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL										
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.00	0.02	0.00	0.00	-0.04	-0.27	-0.44	-0.78	-0.99	-1.01
2	0.00	0.00	0.00	0.00	-0.02	0.03	-0.03	-0.47	-0.75	-0.96	-0.99	-1.00
3	0.00	0.00	0.00	0.00	0.04	-0.04	-0.82	-1.03	-1.19	-1.27	-1.33	-1.37
4	0.01	0.01	-0.02	-0.35	-0.91	-1.74	-2.10	-2.38	-2.52	-2.64	-2.64	-2.56
5	-0.01	-0.01	0.00	0.00	0.00	0.00	-0.02	-0.16	-0.30	-0.39	-0.53	-0.59
6	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.08	-0.22	-0.31	-0.37	-0.35
7	0.00	0.01	0.01	0.04	-0.05	-0.46	-0.70	-0.83	-0.88	-0.90	-0.93	-0.93
8	0.00	0.00	0.00	0.00	0.01	-0.02	-0.33	-0.52	-0.63	-0.74	-0.77	-0.78
9	0.00	-0.02	0.01	-0.02	-0.14	-0.27	-0.25	-0.37	-0.44	-0.46	-0.49	-0.51
10	-0.02	0.00	0.00	0.01	0.06	-0.27	-0.44	-0.68	-0.62	-0.74	-0.71	-0.72
11	-0.01	-0.04	0.01	-0.01	0.00	0.00	-0.03	-0.23	-0.37	-0.37	-0.70	-0.91
12	0.00	0.00	0.00	0.01	-0.06	-0.32	-0.50	-0.74	-0.79	-1.03	-1.08	-1.19
13	0.00	0.00	-0.02	-0.10	-0.41	-0.76	-1.28	-1.45	-1.51	-1.60	-1.66	-1.64
14	0.00	0.00	0.00	0.00	-0.01	0.00	-0.16	-0.41	-0.66	-0.73	-0.80	-0.81
15	0.00	0.01	-0.01	0.00	0.01	0.01	-0.01	-0.02	-0.47	-0.82	-0.92	-0.99
16	0.00	0.01	0.00	-0.02	-0.01	-0.04	-0.11	-0.32	-0.49	-0.60	-0.65	-0.71
17	-0.02	0.01	0.00	0.01	-0.02	-0.15	-0.23	-0.34	-0.33	-0.41	-0.45	-0.50
18	0.00	0.00	0.00	0.00	0.00	-0.03	-0.01	-0.04	-0.10	-0.24	-0.32	-0.42
19	0.00	0.00	0.00	-0.01	0.00	-0.03	-0.08	-0.30	-0.48	-0.69	-0.70	-0.74

678 Hz PROBE FREQUENCY   2 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL										
Ss	66	70	74	78	82	86	90	94	98	102	104
1	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.28	0.62	0.64	0.60
2	0.00	0.00	-0.01	0.01	0.01	0.18	0.42	0.54	0.66	0.62	0.56
3	0.01	0.00	0.01	0.02	0.07	0.34	0.73	0.70	0.60	0.41	0.51
4	-0.06	0.07	-0.05	0.04	-0.05	0.10	0.22	0.55	0.41	-0.03	0.31
5	0.00	-0.01	-0.01	0.00	-0.02	0.00	0.01	0.04	0.06	0.06	0.06
6	0.00	0.00	0.00	-0.01	0.00	-0.01	0.01	0.03	0.02	-0.06	-0.10
7	-0.05	0.03	-0.02	0.01	0.01	0.06	0.07	0.19	0.37	0.31	0.25
8	0.00	0.00	0.00	-0.03	-0.04	-0.02	0.18	0.38	0.50	0.43	0.45
9	0.00	0.00	0.01	0.00	0.12	0.21	0.26	0.20	0.18	0.18	0.19
10	-0.03	0.01	0.02	0.03	-0.01	0.22	0.26	0.28	0.15	0.14	0.10
11	-0.02	0.01	-0.03	0.02	0.01	0.01	0.02	0.01	0.11	0.14	0.16
12	0.00	0.00	0.00	0.02	0.12	0.18	0.31	0.31	0.34	0.33	0.23
13	0.04	0.01	0.07	0.03	0.17	0.30	0.43	0.42	0.25	0.13	0.13
14	0.00	0.00	0.00	0.00	0.01	0.19	0.38	0.32	0.15	0.15	0.12
15	0.01	0.00	0.00	0.00	0.01	-0.01	-0.01	0.00	0.16	0.42	0.43
16	-0.01	-0.01	0.00	0.04	0.16	0.27	0.33	0.32	0.27	0.23	0.20
17	0.00	0.00	0.01	0.00	0.00	0.03	0.03	-0.00	-0.02	-0.06	-0.09
18	-0.02	-0.02	-0.02	0.00	0.00	0.00	-0.04	0.01	0.07	0.15	0.14
19	-0.01	0.01	0.00	0.01	-0.01	0.06	0.25	0.35	0.44	0.64	0.62

678 Hz PROBE FREQUENCY   2 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL										
Ss	66	70	74	78	82	86	90	94	98	102	104
1	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.03	-0.19	-0.69	-0.80
2	-0.01	0.00	0.00	0.00	0.01	-0.01	-0.04	-0.26	-0.46	-0.82	-0.84
3	0.00	0.00	0.00	0.02	0.05	0.04	-0.45	-0.64	-0.51	-0.81	-1.21
4	0.03	0.09	0.08	0.02	-0.06	-0.12	-1.00	-0.97	-1.41	-1.35	-1.77
5	0.00	0.00	0.00	0.00	0.03	0.03	0.00	-0.12	-0.27	-0.28	-0.29
6	0.00	0.00	0.00	0.00	0.03	0.04	0.00	-0.01	-0.16	-0.36	-0.40
7	0.01	-0.02	-0.02	-0.04	0.03	0.02	0.04	-0.07	-0.55	-0.48	-0.73
8	0.00	-0.01	0.00	-0.01	0.01	0.01	0.02	-0.06	-0.29	-0.68	-0.63
9	0.05	0.01	-0.06	0.02	0.01	-0.09	-0.35	-0.53	-0.55	-0.56	-0.56
10	0.00	-0.01	0.00	0.00	0.09	0.03	-0.32	-0.64	-0.59	-0.62	-0.64
11	0.06	-0.07	-0.01	0.04	-0.01	-0.01	-0.05	-0.01	-0.07	-0.20	-0.21
12	0.00	0.00	-0.01	-0.03	-0.07	-0.09	-0.22	-0.32	-0.46	-0.41	-0.56
13	0.00	-0.02	0.00	-0.05	-0.04	-0.23	-0.50	-0.59	-1.14	-1.42	-1.52
14	-0.06	0.00	0.00	-0.02	0.03	-0.12	-0.35	-0.77	-0.90	-0.89	-0.89
15	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.03	-0.32	-0.48
16	0.02	0.00	0.00	-0.04	-0.19	-0.22	-0.40	-0.49	-0.57	-0.63	-0.61
17	0.00	0.00	0.00	0.00	0.00	0.00	-0.16	-0.29	-0.41	-0.37	-0.43
18	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	-0.08	-0.14
19	0.00	-0.01	0.00	-0.01	0.01	-0.02	-0.03	-0.06	-0.11	-0.43	-0.59

1000 Hz PROBE FREQUENCY 0.5 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL											
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.01	0.02	0.05	0.11	0.79	1.36	1.25	1.21	1.18	1.19
2	0.07	0.01	0.01	0.02	0.03	0.19	0.67	1.33	1.23	1.21	1.18	1.19
3	-0.02	0.03	0.03	0.01	0.22	1.13	1.78	2.05	2.00	1.84	1.80	1.73
4	-0.04	-0.02	0.02	-0.02	0.06	1.24	2.95	4.50	4.34	4.05	3.80	3.82
5	0.00	0.00	0.01	0.01	0.01	0.01	0.06	0.23	0.50	0.55	0.58	0.54
6	0.02	-0.02	0.01	0.03	0.02	0.02	-0.03	0.13	0.62	1.11	1.16	1.19
7	-0.02	0.00	0.01	-0.04	-0.08	0.15	0.91	1.44	1.51	1.51	1.41	1.43
8	0.02	0.00	0.00	-0.01	0.03	0.55	0.91	1.02	1.04	1.04	1.00	0.95
9	0.00	0.00	0.00	-0.02	0.02	0.16	0.14	0.21	0.39	0.55	0.66	0.50
10	0.00	-0.02	0.01	0.00	-0.03	0.26	0.75	0.99	1.12	0.97	1.06	1.03
11	-0.06	-0.10	0.05	0.07	-0.01	0.02	0.03	0.13	0.73	1.45	1.64	1.70
12	-0.02	-0.02	-0.02	-0.06	0.16	0.64	1.19	2.53	2.69	2.75	2.70	2.60
13	0.00	0.01	-0.03	-0.02	0.14	0.66	2.63	3.28	3.62	3.65	3.55	3.58
14	0.02	0.05	-0.01	0.01	-0.04	0.01	0.01	0.16	1.09	2.09	2.09	1.96
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.20	1.06	1.72	1.68
16	0.01	0.00	0.01	0.01	0.04	0.25	0.59	0.79	0.84	0.76	0.67	0.66
17	0.03	0.02	0.05	0.10	0.07	0.17	0.60	0.79	0.63	0.94	0.86	0.81
18	-0.02	0.00	-0.01	0.00	0.01	0.00	0.27	0.18	0.37	0.50	0.57	0.59
19	0.00	0.00	0.02	0.03	0.02	0.02	0.13	0.20	0.55	0.68	0.95	0.98

1000 Hz PROBE FREQUENCY 0.5 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL											
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.01	0.02	0.06	0.22	0.39	-0.56	-0.64	-0.71	-0.73	-0.76
2	0.00	0.00	0.04	0.01	0.07	0.15	0.37	-0.43	-0.65	-0.69	-0.71	-0.73
3	0.03	-0.06	0.03	0.11	0.38	0.58	0.00	-0.50	-0.80	-0.97	-1.23	-1.25
4	-0.03	0.33	-0.06	-0.16	0.17	0.52	1.88	0.56	-0.24	-0.89	-1.13	-1.48
5	0.02	0.01	-0.03	0.00	0.00	0.01	0.02	0.01	-0.10	-0.21	-0.28	-0.37
6	-0.02	0.01	-0.03	0.02	0.01	0.03	0.07	0.28	0.52	0.11	0.01	0.07
7	0.00	0.00	0.01	0.01	0.17	0.54	0.82	0.38	-0.01	-0.19	-0.34	-0.51
8	-0.02	-0.01	0.06	0.02	0.26	0.30	-0.02	-0.14	-0.43	-0.53	-0.62	-0.69
9	-0.03	-0.05	-0.05	-0.01	0.06	-0.05	0.01	0.08	0.10	0.10	0.06	0.05
10	0.02	-0.01	-0.02	0.02	0.30	0.33	0.25	-0.24	-0.52	-0.63	-0.67	-0.73
11	0.11	0.08	0.09	-0.06	-0.03	0.05	0.07	0.41	0.22	0.51	0.44	0.22
12	0.01	-0.02	0.02	0.06	0.40	0.55	0.42	-0.05	-0.64	-0.80	-1.14	-1.22
13	-0.02	-0.01	-0.02	0.08	0.52	1.25	1.43	0.97	0.30	-0.28	-0.64	-0.67
14	0.00	0.00	-0.09	0.01	-0.01	-0.02	-0.06	0.72	1.18	0.22	-0.51	-0.87
15	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.18	0.62	0.85	-0.03	0.41
16	0.00	0.00	0.00	0.03	0.02	0.12	0.14	-0.34	-0.55	-0.66	-0.73	-0.75
17	0.04	0.03	0.05	0.08	0.08	0.05	-0.03	-0.14	-0.60	-0.80	-0.90	-1.08
18	0.00	-0.01	0.05	0.00	-0.01	0.01	0.07	0.16	0.23	0.04	-0.01	-0.01
19	0.02	0.05	0.03	0.00	0.08	0.30	0.79	1.31	1.69	1.63	1.54	1.69

1000 Hz PROBE FREQUENCY 1 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL											
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.77	1.21	1.27	1.20	1.21
2	-0.01	0.02	0.01	0.02	0.00	0.03	0.32	1.09	1.29	1.21	1.17	1.16
3	-0.03	-0.02	0.02	-0.04	-0.02	1.14	1.61	1.97	1.97	1.94	1.85	1.79
4	0.03	-0.03	0.13	-0.16	0.12	-0.16	1.52	3.60	4.29	4.38	4.31	4.20
5	0.02	0.01	-0.01	-0.02	-0.02	0.02	0.02	0.38	0.63	0.69	0.66	0.73
6	0.01	0.01	0.03	-0.02	0.02	0.01	0.16	0.65	0.96	1.18	1.23	1.17
7	0.00	-0.03	-0.02	0.00	0.02	0.22	1.10	1.40	1.52	1.43	1.45	1.36
8	0.00	0.01	-0.01	-0.08	-0.05	0.35	0.75	1.00	1.07	1.00	0.93	0.90
9	-0.01	0.11	0.10	-0.01	0.02	-0.04	-0.03	0.48	0.68	0.38	0.81	0.70
10	0.00	-0.01	0.02	0.01	-0.06	0.53	0.82	0.97	0.97	0.92	0.93	0.94
11	0.03	0.04	0.01	-0.04	-0.02	-0.03	0.28	0.41	0.88	1.05	1.22	1.21
12	0.00	0.00	0.01	0.01	0.26	0.55	1.19	1.66	2.11	2.37	2.58	2.64
13	0.00	0.01	-0.08	-0.06	-0.07	-0.07	2.76	2.73	3.59	3.72	3.82	3.96
14	0.00	0.00	0.00	0.00	0.00	-0.01	0.18	1.13	2.00	2.15	2.01	1.89
15	0.00	0.00	0.03	0.00	0.01	0.01	0.02	0.04	0.47	1.50	1.66	1.63
16	-0.03	0.01	0.00	0.00	0.05	0.15	0.63	0.74	0.79	0.71	0.67	0.58
17	0.01	0.00	-0.01	0.00	0.06	0.27	0.65	0.79	0.88	0.94	0.90	0.86
18	-0.01	0.03	-0.02	0.01	0.01	0.02	0.06	0.10	0.21	0.43	0.56	0.62
19	0.00	0.00	0.07	0.01	0.01	0.06	0.15	0.46	0.82	0.99	1.54	1.51

1000 Hz PROBE FREQUENCY 1 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL											
Ss	66	70	74	78	82	86	90	94	98	102	106	110
1	0.03	-0.04	0.06	-0.01	-0.01	-0.02	0.08	0.40	-0.32	-0.60	-0.64	-0.65
2	0.00	0.00	-0.02	0.03	-0.02	0.08	0.27	0.27	-0.14	-0.61	-0.67	-0.72
3	0.00	0.00	0.01	0.02	0.06	0.55	0.48	0.10	-0.45	-0.88	-0.95	-1.17
4	0.07	-0.07	0.00	0.08	0.61	0.65	0.48	2.08	1.56	0.57	-0.71	-0.80
5	-0.05	0.00	0.00	0.00	-0.02	-0.01	0.03	0.15	0.20	-0.23	-0.20	-0.41
6	0.02	0.01	0.02	0.01	0.02	-0.05	0.23	0.51	-0.30	-0.60	-0.62	-0.63
7	0.00	0.00	0.01	0.02	0.32	0.48	0.45	-0.06	-0.59	-0.40	-0.49	-0.60
8	0.00	0.00	0.00	0.06	0.21	0.27	0.12	-0.19	-0.41	-0.55	-0.68	-0.70
9	0.00	0.00	-0.02	-0.06	-0.06	0.05	0.15	0.09	-0.09	-0.16	-0.23	-0.26
10	-0.01	0.00	0.02	-0.01	0.32	0.37	0.02	-0.28	-0.36	-0.54	-0.70	-0.72
11	-0.01	-0.02	0.01	0.01	-0.02	0.02	0.12	0.29	0.27	-0.05	-0.18	-0.46
12	0.00	0.00	0.00	0.10	0.22	0.55	0.68	0.51	0.25	-0.63	-0.60	-0.82
13	0.02	-0.02	0.01	0.16	0.59	1.55	1.57	1.19	0.14	-0.04	-0.36	-0.81
14	0.00	0.01	-0.01	0.00	-0.01	-0.02	0.29	0.55	-0.05	-0.52	-0.95	-1.04
15	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.16	0.86	0.72	-0.06	-0.39
16	0.01	0.00	0.00	0.01	0.01	0.05	-0.14	-0.40	-0.55	-0.60	-0.72	-0.72
17	0.02	0.00	0.00	0.01	0.06	0.04	-0.05	-0.26	-0.44	-0.64	-0.78	-0.90
18	0.00	0.00	0.00	0.00	0.03	0.03	0.04	0.09	0.16	0.20	0.04	0.01
19	0.00	0.00	-0.01	-0.03	0.01	0.46	0.53	0.92	1.01	0.98	0.87	0.72

1000 Hz PROBE FREQUENCY   2 kHz STIMULUS FREQUENCY

SUSCEPTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL										
Ss	66	70	74	78	82	86	90	94	98	102	104
1	0.00	-0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.42	0.61	1.26
2	0.00	-0.01	0.00	0.00	0.01	0.02	0.14	0.33	0.43	0.62	0.94
3	0.00	-0.01	0.00	0.04	0.03	0.36	1.56	1.65	1.88	1.89	1.75
4	-0.07	0.11	0.05	-0.10	-0.05	0.09	-0.22	-0.16	-0.19	3.83	4.47
5	-0.01	-0.01	0.02	-0.01	0.01	0.01	0.47	0.67	0.60	0.63	0.62
6	0.03	-0.02	0.01	0.01	0.01	0.03	0.07	0.42	1.06	1.21	1.19
7	0.01	0.01	0.02	0.03	-0.01	-0.05	-0.02	0.18	0.92	1.43	1.52
8	0.01	0.00	-0.01	0.01	-0.01	-0.07	0.06	0.37	0.85	0.99	1.00
9	0.03	-0.04	-0.04	-0.06	-1.75	0.36	0.39	0.54	0.56	0.64	0.59
10	0.00	0.02	0.01	-0.02	-0.03	-0.08	0.36	0.76	0.77	0.93	0.89
11	-0.02	-0.02	-0.01	-0.02	0.02	-0.02	0.06	0.17	0.29	0.51	0.90
12	0.01	0.00	-0.01	-0.02	-0.02	0.32	0.49	0.37	1.20	1.39	2.22
13	0.01	0.00	0.00	-0.01	0.00	0.02	0.18	0.29	0.27	2.61	3.54
14	0.02	0.01	-0.02	0.02	0.01	0.32	0.48	2.39	2.79	2.92	2.84
15	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.03	0.49	1.06
16	0.01	0.01	0.01	0.10	0.26	0.51	0.69	0.70	0.65	0.67	0.63
17	-0.01	-0.01	0.03	0.00	0.03	0.28	0.79	0.93	0.98	0.90	0.90
18	-0.01	-0.03	0.00	0.00	0.01	0.01	-0.03	0.03	0.09	0.50	0.40
19	0.01	0.00	0.00	0.04	0.01	0.06	0.03	0.05	0.25	0.59	1.11

1000 Hz PROBE FREQUENCY   2 kHz STIMULUS FREQUENCY

CONDUCTANCE VALUES RECORDED ACROSS THE RANGE OF STIMULUS INTENSITIES.

	dBHL										
Ss	66	70	74	78	82	86	90	94	98	102	104
1	0.02	0.01	0.00	-0.01	0.00	0.01	0.04	0.37	0.46	0.37	0.12
2	-0.03	-0.01	0.00	0.00	0.02	0.07	0.21	0.38	0.98	0.49	0.29
3	0.02	0.04	0.03	0.06	0.08	0.21	0.35	0.62	-0.14	-0.66	-0.93
4	0.01	0.01	0.02	0.06	0.35	0.48	0.35	1.88	2.16	2.69	2.61
5	0.01	0.00	0.09	0.09	0.13	0.11	0.12	-0.28	-0.38	-0.46	-0.51
6	0.03	0.03	0.06	0.04	0.07	0.09	0.14	0.42	0.03	-0.46	-0.62
7	0.00	-0.01	0.00	0.00	0.00	0.10	0.27	0.41	0.70	0.78	0.12
8	0.00	0.00	0.00	0.00	0.03	0.09	0.31	0.32	-0.20	-0.35	-0.42
9	0.03	0.06	0.06	0.07	0.06	0.09	0.31	-0.12	-0.20	-0.16	-0.17
10	0.00	-0.04	0.00	0.00	0.10	0.23	0.39	0.19	-0.03	-0.28	-0.28
11	0.02	0.01	0.00	0.01	0.03	0.00	0.04	0.14	0.22	0.51	0.60
12	-0.01	0.02	-0.01	0.02	0.09	0.15	0.18	0.35	0.58	0.62	0.04
13	0.00	0.00	0.00	0.08	0.15	0.27	0.68	0.93	1.42	1.31	1.21
14	0.01	0.03	0.03	0.00	0.00	0.60	1.02	1.05	0.36	-0.36	-0.31
15	0.02	0.00	0.00	-0.01	-0.01	0.01	0.02	0.02	0.14	0.41	0.70
16	0.01	0.01	0.00	0.02	0.10	0.03	-0.12	-0.36	-0.56	-0.65	-0.67
17	0.02	0.00	-0.01	-0.01	0.00	0.06	0.04	-0.16	-0.55	-0.72	-0.83
18	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.12	0.16	0.25	0.27
19	0.01	0.00	0.00	0.01	0.01	0.11	0.35	0.62	0.87	1.47	1.42

APPENDIX C

Diphasic Reflexes Recorded in Part One. These Reflexes are displayed according to Subject, Component, Probe Frequency, Stimulus Frequency and Stimulus Intensity.

DIPHASIC REFLEXES RECORDED FOR PART ONE.

Subject	Component B/G	Probe Frequency Hz	Stimulus Frequency kHz	Stimulus Intensity dB HL
9	G	226	1	90
9	G	226	1	106
9	G	226	1	110
14	G	226	0.5	98
8	G	678	1	86
10	G	678	1	78
10	G	678	2	86
12	G	678	0.5	82
12	G	678	2	104
13	G	678	1	82
17	G	678	1	78
18	G	678	0.5	110
2	G	1000	1	98
3	G	1000	0.5	90
3	G	1000	1	94
3	G	1000	2	98
5	G	1000	0.5	70
5	G	1000	0.5	94
5	G	1000	2	90
5	G	1000	2	98
6	G	1000	0.5	106
6	G	1000	2	98
7	G	1000	0.5	98
7	G	1000	1	94
7	G	1000	1	98
7	G	1000	1	102
8	G	1000	0.5	90
8	G	1000	1	90
8	G	1000	1	94
9	G	1000	1	94
10	G	1000	1	90
10	G	1000	1	98
10	G	1000	2	94
10	G	1000	2	98
10	G	1000	2	102
10	G	1000	2	104
11	G	1000	0.5	82
11	G	1000	0.5	98
11	G	1000	0.5	110
11	G	1000	1	102
11	G	1000	1	106
11	G	1000	1	110
12	G	1000	0.5	94
12	G	1000	1	102
13	G	1000	0.5	98
13	G	1000	0.5	102
13	G	1000	0.5	106
13	G	1000	0.5	110

Subject	Component B/G	Probe Frequency Hz	Stimulus Frequency kHz	Stimulus Intensity dB-HL
13	G	1000	1	98
13	G	1000	1	102
13	G	1000	1	106
13	G	1000	1	110
14	G	1000	0.5	102
14	G	1000	0.5	106
14	G	1000	1	98
14	G	1000	1	102
14	G	1000	1	106
14	G	1000	1	110
14	G	1000	2	98
14	G	1000	2	102
14	G	1000	2	104
15	G	1000	0.5	106
15	G	1000	1	106
15	G	1000	1	110
16	G	1000	2	86
17	G	1000	0.5	90
17	G	1000	0.5	92
14	B	226	1	70
14	B	226	1	82
5	B	678	2	102
5	B	678	2	104
9	B	678	0.5	106
10	B	678	0.5	82
10	B	678	2	98
11	B	678	1	90
11	B	678	2	94
13	B	678	1	106
13	B	678	1	110
13	B	678	2	102
13	B	678	2	104
14	B	678	1	106
14	B	678	2	98
14	B	678	2	102
14	B	678	2	104
7	B	1000	0.5	74
9	B	1000	1	82
9	B	1000	2	82
11	B	1000	1	94
12	B	1000	2	104
13	B	1000	0.5	70
13	B	1000	2	82
13	B	1000	2	86
13	B	1000	2	90
13	B	1000	2	94
13	B	1000	2	98
13	B	1000	2	104

APPENDIX D

Transmission Properties for the 30 Ears used in Part Two at the 1000Hz Probe Frequency, and the division of Ears into Groups.

TRANSMISSION PROPERTIES OF EARS AT THE 1000 Hz PROBE SIGNAL WHICH FORMED THE BASIS FOR THE DIVISION OF THE 30 EARS INTO 5 GROUPS.

GROUP 1	Type 1 tympanograms (1B1G). All tympanometric peak B values larger than tympanometric peak G values, and all B values positive.
SUBJECTS	6, 15, 18, 21, 22, 25, 26, 28, 29
GROUP 2	Type 2 tympanograms (3B1G). All tympanometric peak B values larger than G values and all B values positive
SUBJECTS	16, 20, 24, 27
GROUP 3	Type 2 tympanograms (3B1G). All tympanometric peak B values smaller than tympanometric peak G values and all B values positive.
SUBJECTS	1, 3, 13, 18, 23, 30
GROUP 4	Type 3 tympanograms (3B3G). All tympanometric peak B values smaller than tympanometric peak G values and all B values positive.
SUBJECTS	2, 5, 7, 8, 10, 11, 17
GROUP 5	Type 3 tympanograms (3B3G). All tympanometric B values negative.
SUBJECTS	4, 9, 12, 14

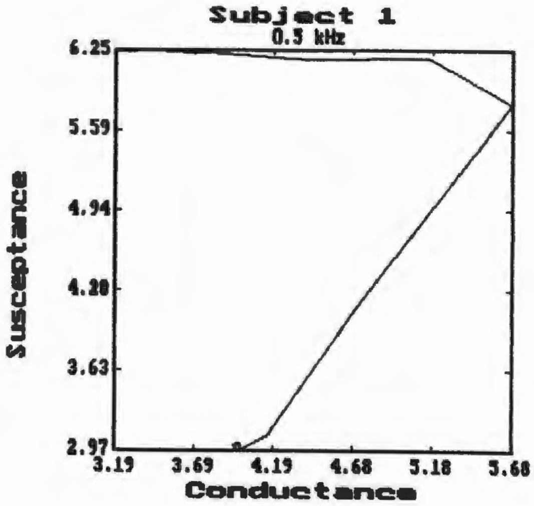
APPENDIX E

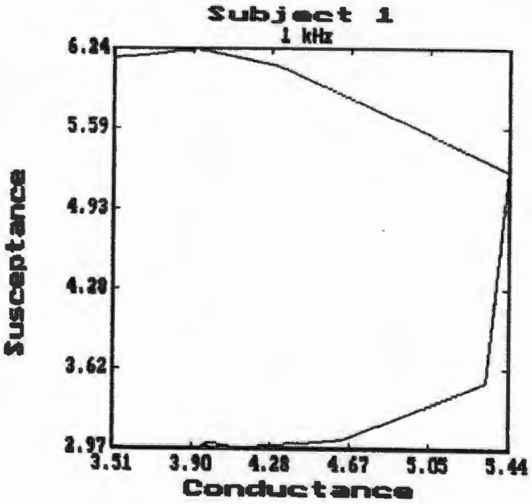
Phasor Diagrams for the 30 Subjects in Part Two for Reflex Patterns at 0.5, 1 And 2 kHz Stimuli at the 1000Hz Probe Frequency.

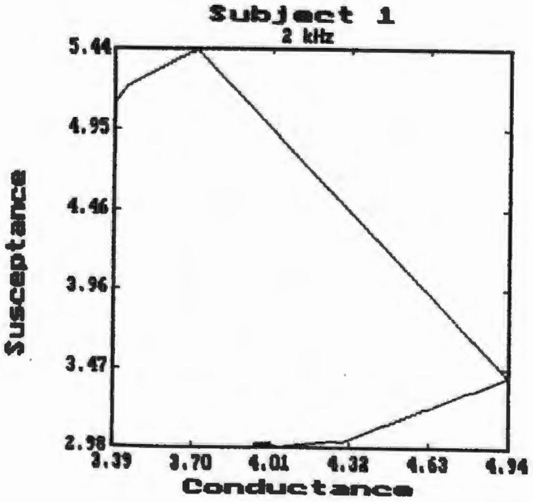
Accompanying tables indicate the mmho value recorded at each intensity level, added to the baseline value obtained from susceptance and conductance tympanograms at the 1000 hz probe frequency.
In addition, the classification of susceptance (B) and conductance (G) at threshold and suprathreshold levels as either + or - is indicated.

Diphasic conductance patterns are indicated by D:G
Diphasic susceptance patterns are indicated by D:B

0 dB HL refers to the baseline tympanometric peak values observed at the 1000 Hz probe frequency.







Subject 1 0.5 kHz

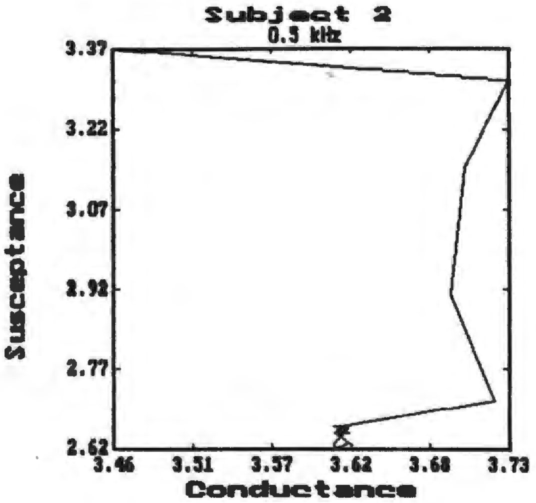
dB HL	Bm	Gm	Type
0	3.00	3.95	
66	3.01	3.94	
70	2.98	3.95	
74	3.02	3.95	
78	3.02	3.98	
82	2.97	3.98	
86	3.09	4.15	
90	4.17	4.72	+B+G
94	5.80	5.68	
98	6.18	5.16	
102	6.17	4.41	D:G
106	6.25	3.45	+B-G
110	6.24	3.19	

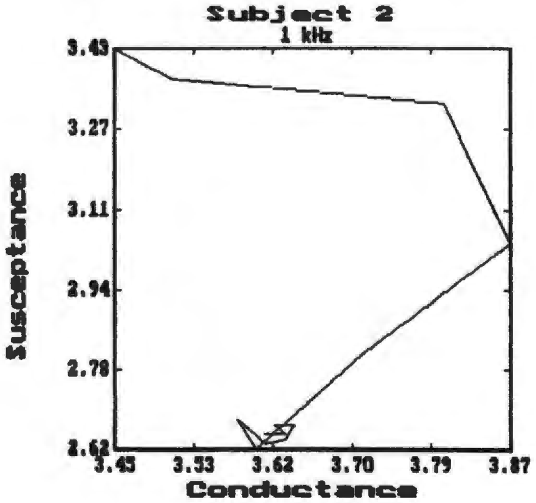
Subject 1 1 kHz

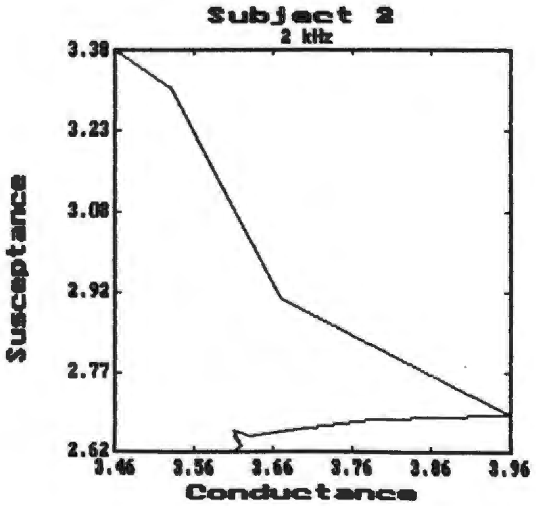
dB HL	Bm	Gm	Type
0	3.00	3.95	
66	3.00	3.97	
70	2.98	3.95	
74	2.98	3.94	
78	3.01	3.97	
82	2.97	4.13	
86	3.04	4.63	
90	3.51	5.33	+B+G
94	5.25	5.44	
98	6.11	4.30	D:G
102	6.24	3.91	D:G
106	6.19	3.66	+B-G
110	6.17	3.51	

Subject 1 2 kHz

dB HL	Bm	Gm	Type
0	3.00	3.95	
66	3.00	3.95	
70	3.00	3.97	
74	3.00	4.00	
78	2.99	3.95	
82	3.00	3.96	
86	2.98	4.04	
90	3.02	4.29	
94	3.42	4.94	+B+G
98	5.44	3.71	D:G
102	5.22	3.44	+B-G
104	5.11	3.39	







Subject 2 0.5 kHz

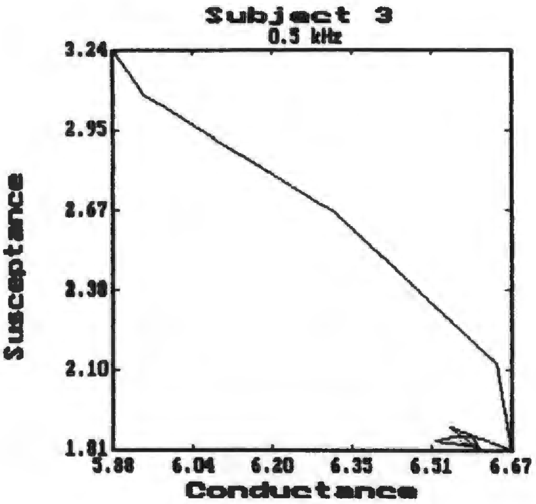
dB HL	Bm	Gm	Type
0	2.65	3.61	
66	2.63	3.62	
70	2.62	3.61	
74	2.63	3.61	
78	2.66	3.62	
82	2.65	3.61	
86	2.65	3.62	
90	2.66	3.61	
94	2.71	3.72	
98	2.91	3.69	
102	3.15	3.70	+B+G
106	3.31	3.73	
110	3.37	3.46	+B-G

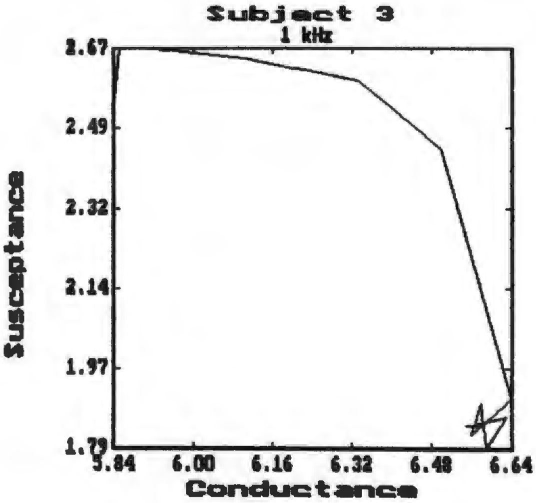
Subject 2 1 kHz

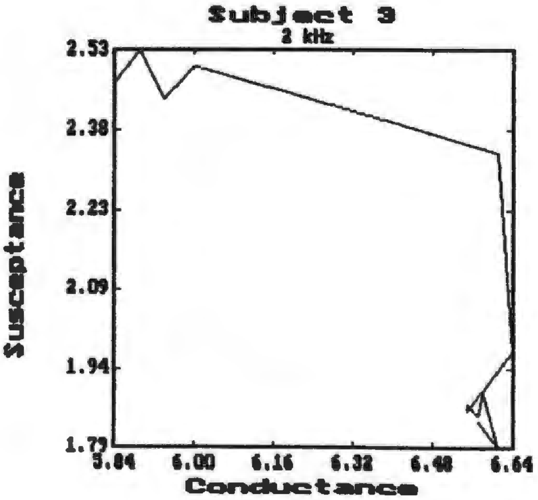
dB HL	Bm	Gm	Type
0	2.65	3.61	
66	2.65	3.63	
70	2.67	3.62	
74	2.67	3.64	
78	2.64	3.63	
82	2.63	3.61	
86	2.68	3.58	
90	2.62	3.60	
94	2.81	3.71	+B+G
98	3.04	3.87	
102	3.32	3.80	
106	3.37	3.61	
110	3.43	3.45	+B-G

Subject 2 2 kHz

dB HL	Bm	Gm	Type
0	2.65	3.61	
66	2.63	3.62	
70	2.62	3.61	
74	2.63	3.62	
78	2.66	3.61	
82	2.65	3.63	
86	2.65	3.63	
90	2.68	3.78	
94	2.69	3.96	+B+G
98	2.91	3.67	D:G
102	3.31	3.53	+B-G
104	3.38	3.46	







Subject 3 0.5 kHz

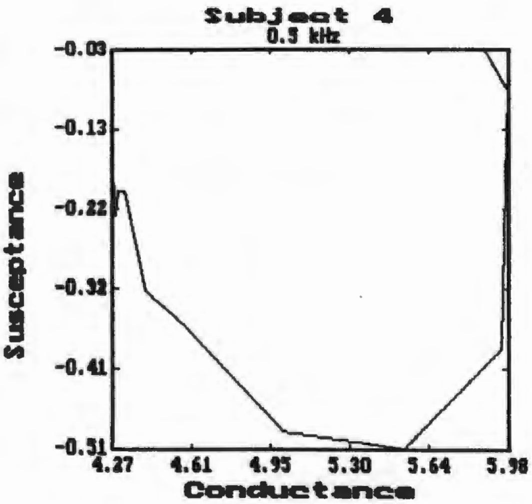
dB HL	Bm	Gm	Type
0	1.84	6.57	
66	1.81	6.61	
70	1.86	6.59	
74	1.86	6.56	
78	1.84	6.52	
82	1.82	6.60	
86	1.89	6.55	
90	1.81	6.67	
94	2.12	6.64	+B+G
98	2.66	6.32	+B-G
102	2.97	6.04	
106	3.08	5.94	
110	3.24	5.88	

Subject 3 1 kHz

dB HL	Bm	Gm	Type
0	1.84	6.57	
66	1.84	6.55	
70	1.86	6.63	
74	1.79	6.59	
78	1.89	6.58	
82	1.82	6.56	
86	1.90	6.64	
90	2.45	6.50	
94	2.60	6.33	+B-G
98	2.65	6.10	
102	2.67	5.92	
106	2.67	5.85	
110	2.56	5.84	

Subject 3 2 kHz

dB HL	Bm	Gm	Type
0	1.84	6.57	
66	1.79	6.61	
70	1.89	6.58	
74	1.85	6.57	
78	1.87	6.55	
82	1.86	6.55	
86	1.97	6.64	+B+G
90	2.34	6.61	
94	2.50	6.00	+B-G
98	2.44	5.94	
102	2.53	5.89	
104	2.47	5.84	

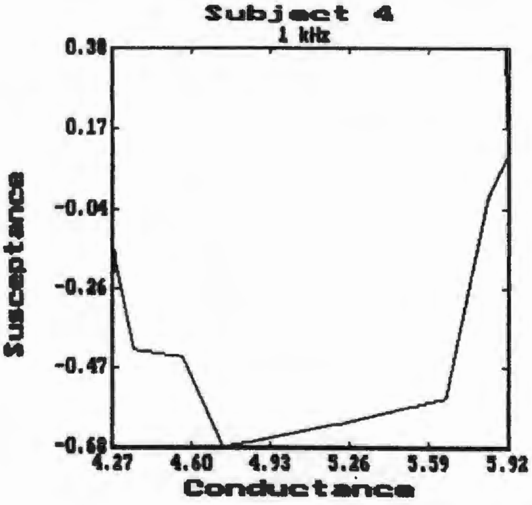


Subject 4 0.5 kHz

dB HL	Bm	Gm	Type
0	-0.19	4.27	
66	-0.18	4.27	
70	-0.23	4.28	
74	-0.20	4.29	
78	-0.20	4.32	
82	-0.32	4.41	-B+G
86	-0.36	4.57	
90	-0.49	5.01	
94	-0.51	5.53	
98	-0.39	5.95	
102	-0.19	5.97	D:B
106	-0.08	5.98	+B+G
110	-0.03	5.88	

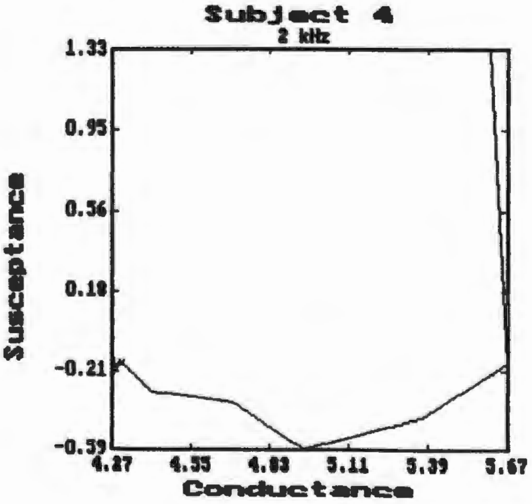
Subject 4 1 kHz

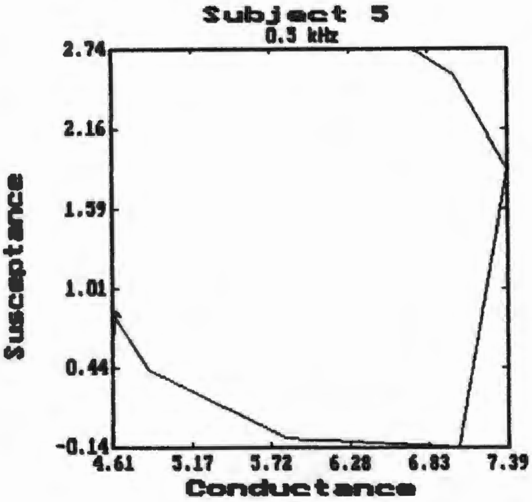
dB HL	Bm	Gm	Type
0	-0.19	4.27	
66	-0.17	4.27	
70	-0.23	4.27	
74	-0.16	4.28	
78	-0.15	4.27	
82	-0.42	4.36	-B+G
86	-0.44	4.56	
90	-0.68	4.73	
94	-0.62	5.20	
98	-0.55	5.66	
102	-0.01	5.84	D:B
106	0.10	5.92	+B+G
110	0.38	5.91	

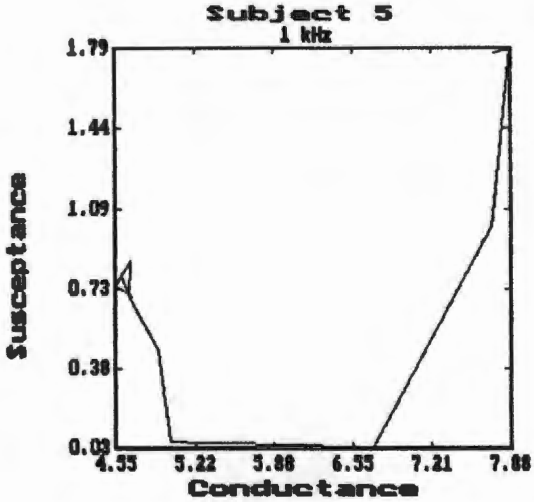


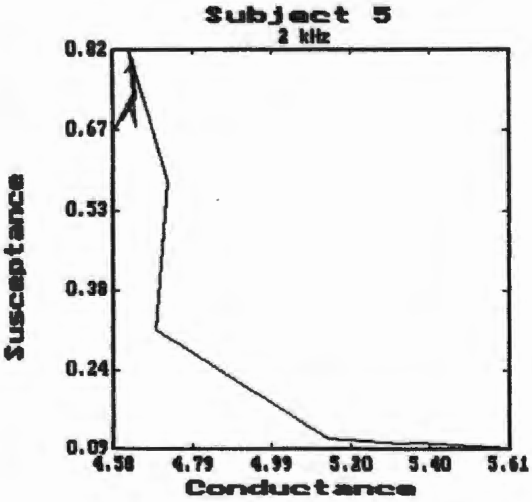
Subject 4 2 kHz

dB HL	Bm	Gm	Type
0	-0.19	4.27	
66	-0.16	4.31	
70	-0.19	4.28	
74	-0.13	4.27	
78	-0.23	4.27	
82	-0.16	4.30	
86	-0.31	4.41	-B+G
90	-0.36	4.70	
94	-0.59	4.95	
98	-0.43	5.37	
102	-0.17	5.67	D:B
104	1.33	5.61	+B+G









Subject 5 0.5 kHz

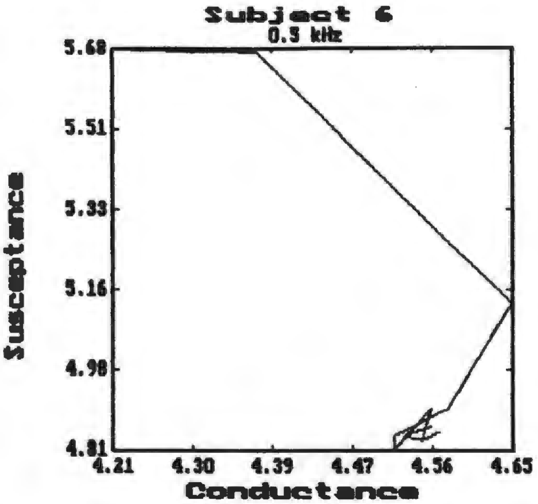
dB HL	Bm	Gm	Type
0	0.78	4.61	
66	0.85	4.63	
70	0.81	4.67	
74	0.83	4.64	
78	0.83	4.62	
82	0.70	4.62	
86	0.81	4.62	
90	0.42	4.86	-B+G
94	-0.08	5.83	
98	-0.14	7.05	
102	1.87	7.39	+B+G
106	2.55	7.02	
110	2.74	6.79	

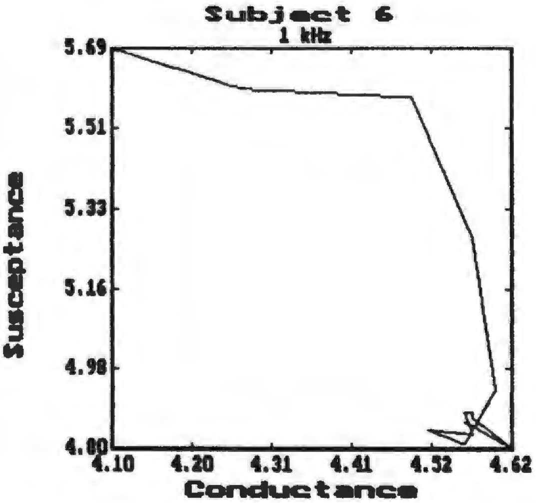
Subject 5 1 kHz

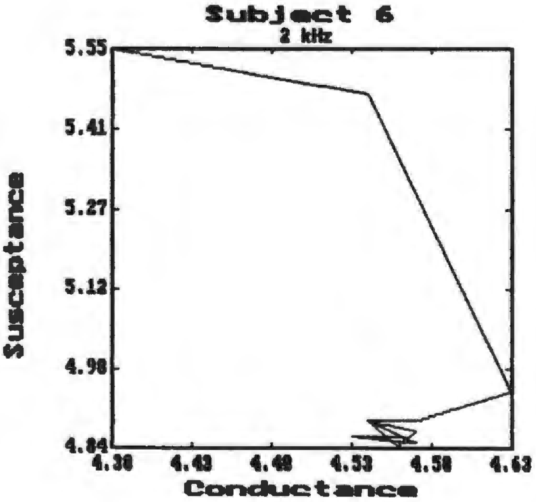
dB HL	Bm	Gm	Type
0	0.78	4.61	
66	0.75	4.63	
70	0.70	4.68	
74	0.75	4.55	
78	0.86	4.67	
82	0.85	4.67	
86	0.70	4.66	
90	0.46	4.90	-B+G
94	0.06	5.00	
98	0.03	6.72	
102	1.01	7.72	+B+G
106	1.79	7.88	
110	1.77	7.75	

Subject 5 2 kHz

dB HL	Bm	Gm	Type
0	0.78	4.61	
66	0.80	4.63	
70	0.73	4.64	
74	0.67	4.58	
78	0.74	4.63	
82	0.72	4.62	
86	0.68	4.64	
90	0.82	4.62	
94	0.58	4.72	-B+G
98	0.31	4.69	
102	0.11	5.14	
104	0.09	5.61	







Subject 6 0.5 kHz

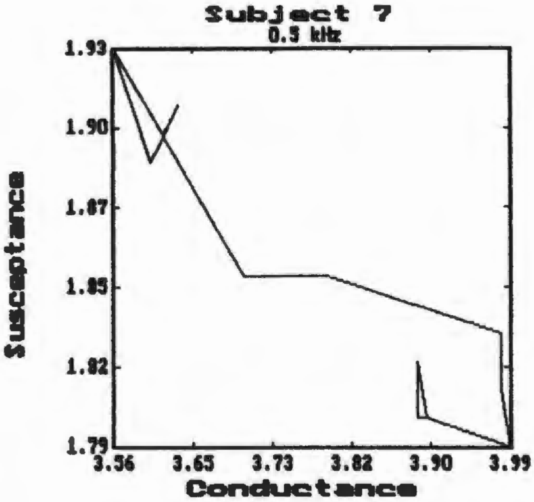
dB HL	Bm	Gm	Type
0	4.86	4.56	
66	4.84	4.53	
70	4.83	4.55	
74	4.85	4.57	
78	4.83	4.55	
82	4.90	4.56	
86	4.81	4.52	
90	4.84	4.52	
94	4.90	4.58	
98	5.13	4.65	+B+G
102	5.28	4.57	D:G
106	5.67	4.37	+B-G
110	5.68	4.21	

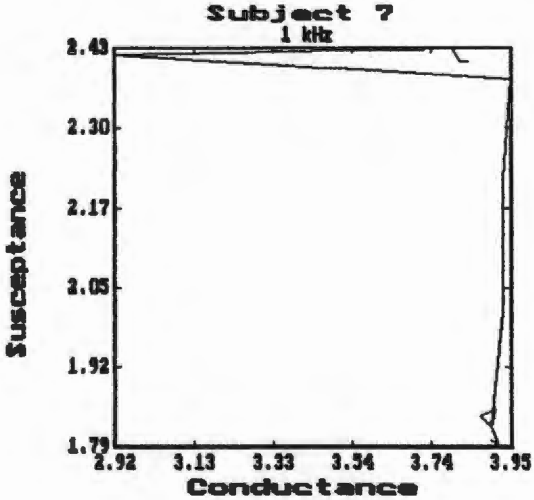
Subject 6 1 kHz

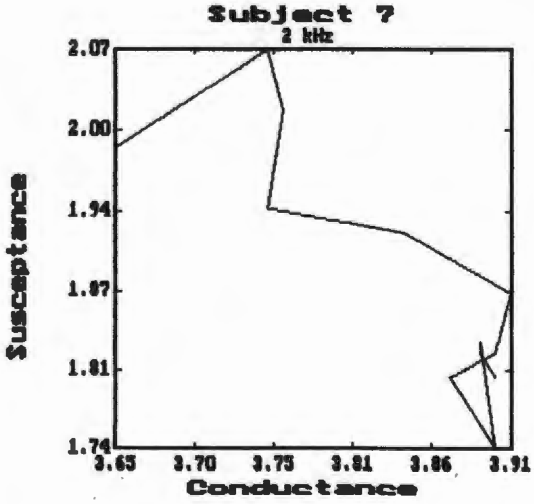
dB HL	Bm	Gm	Type
0	4.86	4.56	
66	4.80	4.62	
70	4.87	4.57	
74	4.88	4.57	
78	4.88	4.56	
82	4.83	4.57	
86	4.84	4.51	
90	4.81	4.56	
94	4.93	4.60	
98	5.27	4.57	
102	5.58	4.49	
106	5.60	4.27	+B-G
110	5.69	4.10	

Subject 6 2 kHz

dB HL	Bm	Gm	Type
0	4.86	4.56	
66	4.86	4.53	
70	4.85	4.57	
74	4.89	4.54	
78	4.84	4.56	
82	4.85	4.56	
86	4.87	4.57	
90	4.89	4.54	
94	4.89	4.57	
98	4.94	4.63	+B+G
102	5.47	4.54	D:G
104	5.55	4.38	+B-G







Subject 7 0.5 kHz

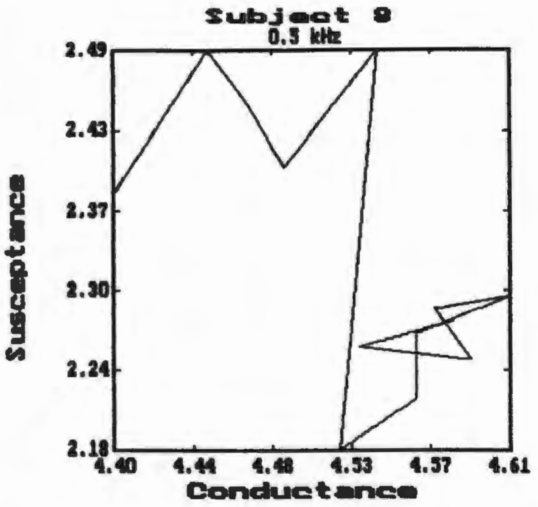
dB HL	Bm	Gm	Type
0	1.80	3.90	
66	1.82	3.89	
70	1.80	3.89	
74	1.80	3.89	
78	1.80	3.90	
82	1.79	3.99	
86	1.81	3.98	
90	1.83	3.98	
94	1.85	3.79	
98	1.85	3.70	
102	1.93	3.56	+B-G
106	1.89	3.60	
110	1.91	3.63	

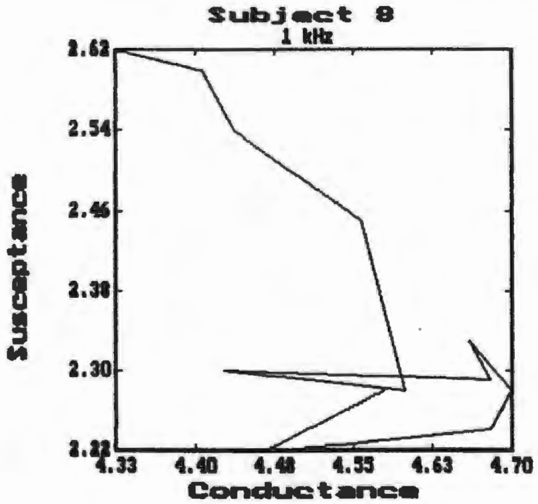
Subject 7 1 kHz

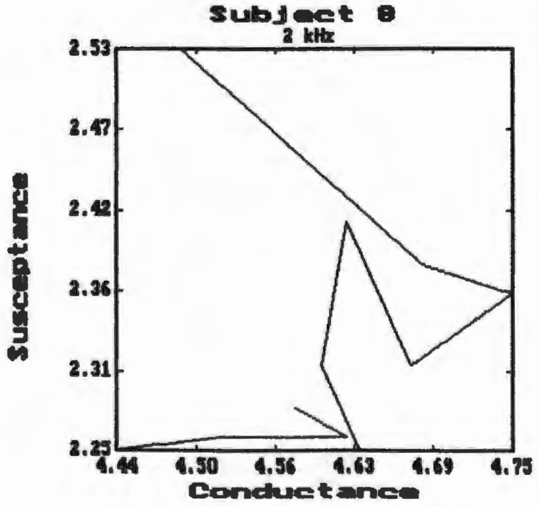
dB HL	Bm	Gm	Type
0	1.80	3.90	
66	1.79	3.92	
70	1.82	3.90	
74	1.85	3.91	
78	1.84	3.87	
82	1.82	3.90	
86	2.01	3.93	
90	2.22	3.93	
94	2.38	3.95	
98	2.42	2.92	+B-G
102	2.43	3.80	
106	2.41	3.82	
110	2.41	3.84	

Subject 7 2 kHz

dB HL	Bm	Gm	Type
0	1.80	3.90	
66	1.82	3.89	
70	1.83	3.89	
74	1.74	3.90	
78	1.80	3.87	
82	1.82	3.90	
86	1.87	3.91	
90	1.92	3.84	
94	1.94	3.75	+B-G
98	2.02	3.76	
102	2.07	3.75	
104	1.99	3.65	







Subject 8 0.5 kHz

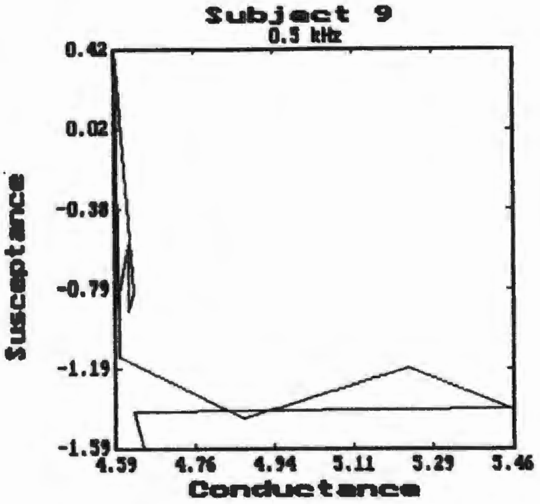
dB HL	Bm	Gm	Type
0	2.28	4.58	
66	2.26	4.53	
70	2.25	4.59	
74	2.29	4.57	
78	2.30	4.61	
82	2.27	4.56	
86	2.22	4.56	
90	2.18	4.52	
94	2.49	4.54	
98	2.40	4.49	
102	2.45	4.47	
106	2.49	4.45	+B-G
110	2.38	4.40	

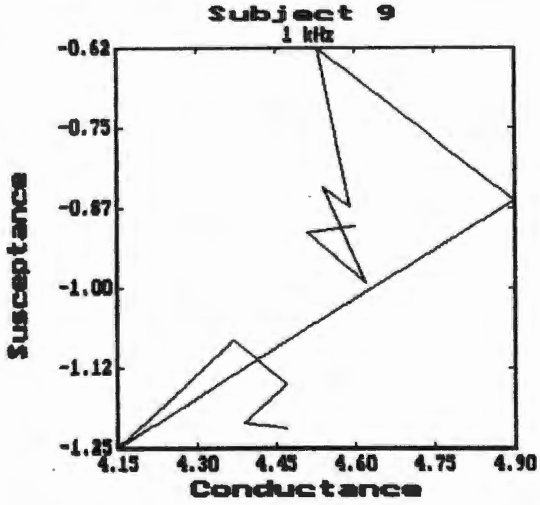
Subject 8 1 kHz

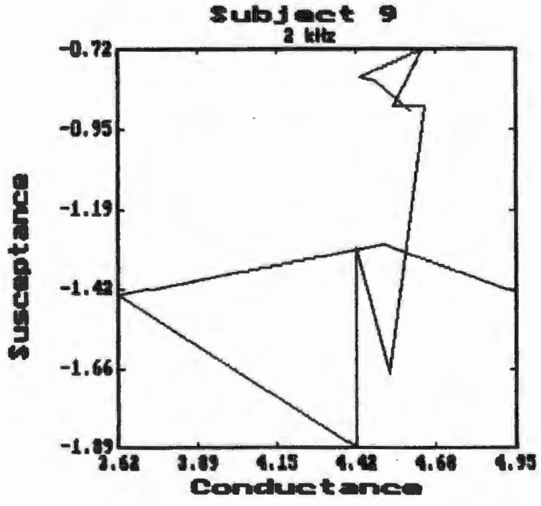
dB HL	Bm	Gm	Type
0	2.28	4.58	
66	2.22	4.47	
70	2.22	4.49	
74	2.24	4.68	
78	2.28	4.70	
82	2.33	4.66	
86	2.29	4.68	
90	2.30	4.43	
94	2.28	4.60	
98	2.45	4.56	
102	2.54	4.44	+B-G
106	2.60	4.41	
110	2.62	4.33	

Subject 8 2 kHz

dB HL	Bm	Gm	Type
0	2.28	4.58	
66	2.26	4.62	
70	2.26	4.52	
74	2.25	4.44	
78	2.25	4.63	
82	2.25	4.63	
86	2.31	4.60	
90	2.41	4.62	
94	2.31	4.67	
98	2.36	4.75	+B+G
102	2.38	4.68	
104	2.53	4.49	+B-G







Subject 9 0.5 kHz

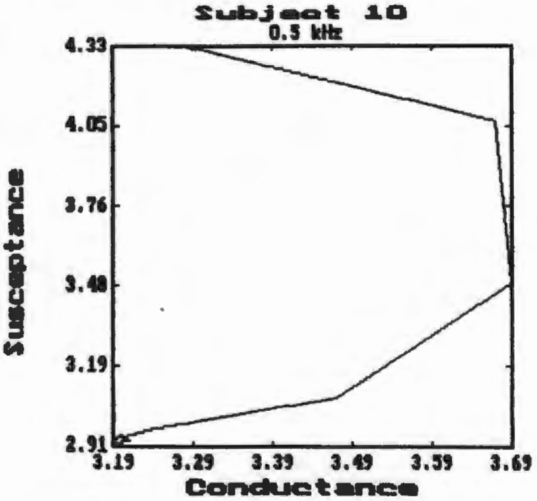
dB HL	Bm	Gm	Type
0	-0.90	4.60	
66	-0.81	4.60	
70	-0.56	4.62	
74	-0.90	4.62	
78	-0.80	4.63	
82	0.42	4.59	
86	-1.13	4.60	
90	-1.29	4.74	-B+G
94	-1.44	4.87	
98	-1.18	5.23	
102	-1.39	5.46	
106	-1.41	4.63	D:G
110	-1.29	4.65	D:G

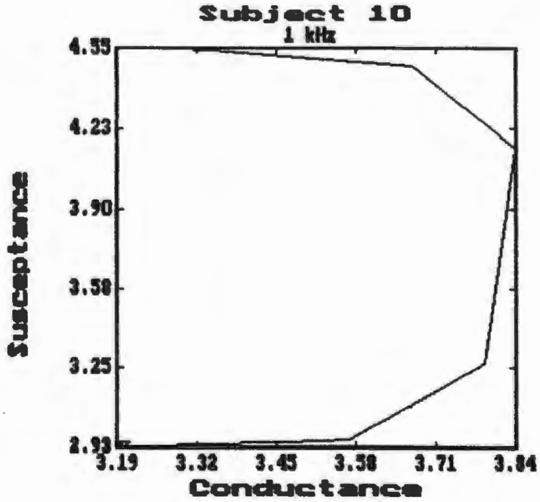
Subject 9 1 kHz

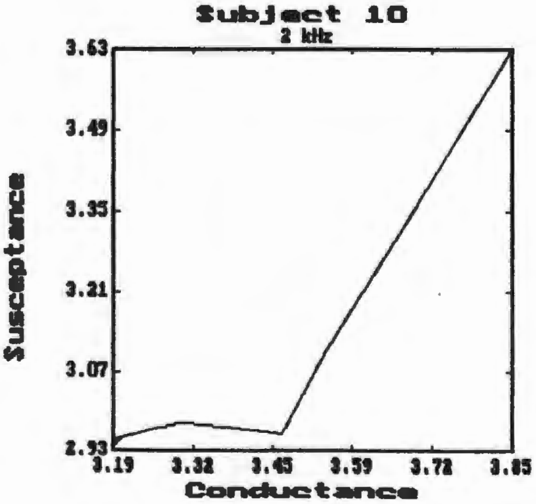
dB HL	Bm	Gm	Type
0	-0.90	4.60	
66	-0.91	4.51	
70	-0.99	4.62	
74	-0.84	4.54	
78	-0.87	4.59	
82	-0.62	4.53	
86	-0.86	4.90	
90	-1.05	4.53	-B-G
94	-1.25	4.15	
98	-1.08	4.37	D:B
102	-1.15	4.47	D:B
106	-1.21	4.39	D:B
110	-1.22	4.47	D:B

Subject 9 2 kHz

dB HL	Bm	Gm	Type
0	-0.90	4.60	
66	-0.81	4.48	
70	-0.80	4.43	
74	-0.72	4.64	
78	-0.89	4.54	
82	-0.89	4.65	
86	-1.67	4.53	
90	-1.30	4.42	
94	-1.89	4.42	-B-G
98	-1.44	3.62	
102	-1.29	4.51	
104	-1.43	4.95	D:G







Subject 10 0.5 kHz

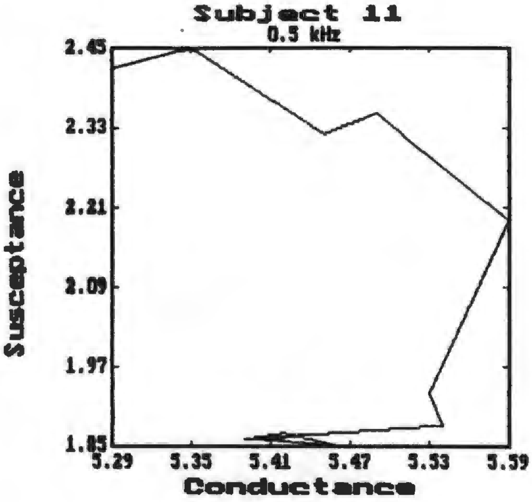
dB HL	Bm	Gm	Type
0	2.93	3.19	
66	2.95	3.20	
70	2.93	3.19	
74	2.91	3.20	
78	2.93	3.20	
82	2.93	3.20	
86	2.93	3.21	
90	2.94	3.20	
94	2.97	3.24	
98	3.08	3.47	+B+G
102	3.49	3.69	
106	4.06	3.67	
110	4.33	3.28	D:G

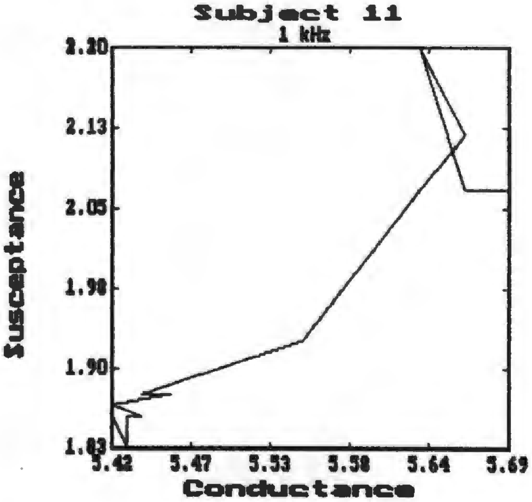
Subject 10 1 kHz

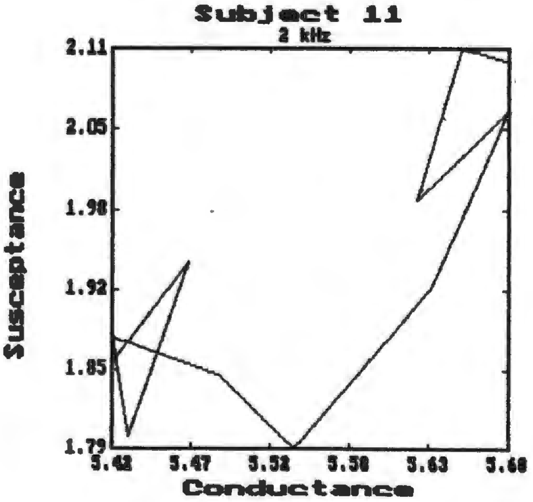
dB HL	Bm	Gm	Type
0	2.93	3.19	
66	2.95	3.20	
70	2.95	3.20	
74	2.95	3.20	
78	2.95	3.19	
82	2.95	3.21	
86	2.93	3.20	
90	2.93	3.21	
94	2.96	3.57	
98	3.27	3.79	+B+G
102	4.15	3.84	
106	4.48	3.67	
110	4.55	3.30	D:G

Subject 10 2 kHz

dB HL	Bm	Gm	Type
0	2.93	3.19	
66	2.93	3.19	
70	2.93	3.19	
74	2.94	3.19	
78	2.95	3.20	
82	2.95	3.20	
86	2.95	3.20	
90	2.95	3.19	
94	2.98	3.30	
98	2.96	3.47	
102	3.10	3.54	+B+G
104	3.63	3.85	







Subject 11 0.5 kHz

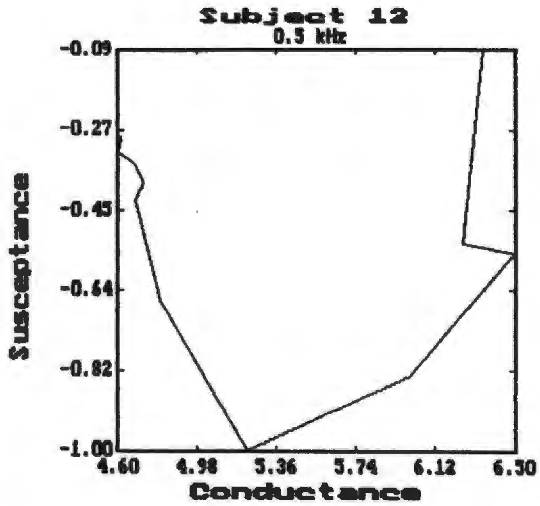
dB HL	Bm	Gm	Type
0	1.86	5.42	
66	1.86	5.42	
70	1.86	5.40	
74	1.85	5.46	
78	1.87	5.42	
82	1.86	5.39	
86	1.88	5.54	
90	1.93	5.53	
94	2.19	5.59	+B+G
98	2.35	5.49	
102	2.32	5.45	
106	2.45	5.35	
110	2.42	5.29	+B-G

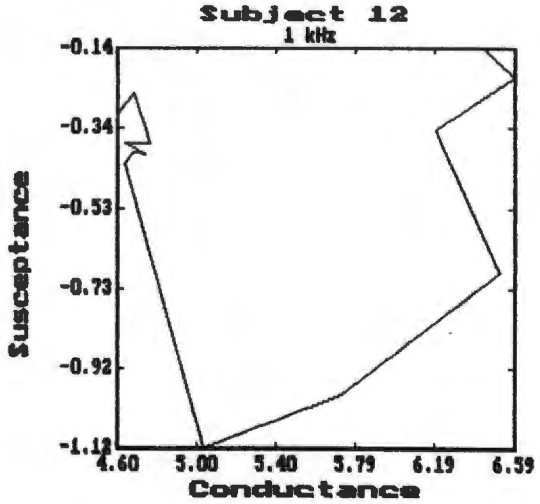
Subject 11 1 kHz

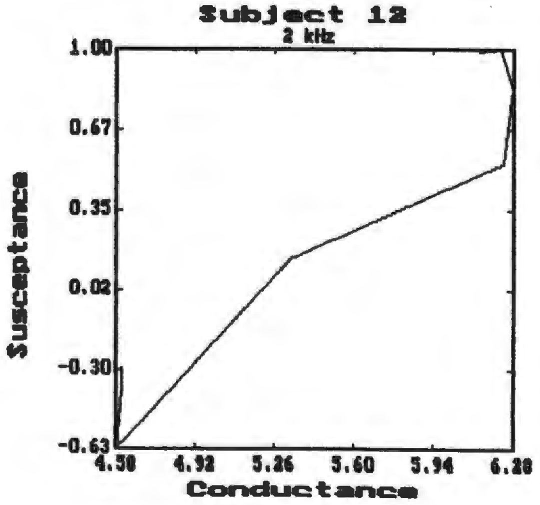
dB HL	Bm	Gm	Type
0	1.86	5.42	
66	1.83	5.43	
70	1.86	5.43	
74	1.86	5.44	
78	1.87	5.42	
82	1.88	5.46	
86	1.88	5.44	
90	1.93	5.55	
94	2.07	5.63	+B+G
98	2.12	5.66	
102	2.20	5.63	
106	2.07	5.66	D:G
110	2.07	5.69	

Subject 11 2 kHz

dB HL	Bm	Gm	Type
0	1.86	5.42	
66	1.86	5.42	
70	1.94	5.47	
74	1.80	5.43	
78	1.88	5.42	
82	1.85	5.49	
86	1.79	5.54	
90	1.92	5.63	
94	2.06	5.68	+B+G
98	1.99	5.62	
102	2.11	5.65	
104	2.10	5.68	


Subject 12
0.5 kHz


Subject 12
1 kHz


Subject 12
2 kHz

Subject 12 0.5 kHz

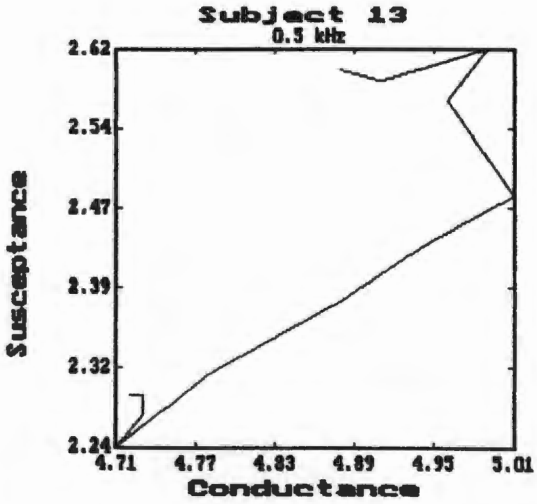
dB HL	Bm	Gm	Type
0	-0.30	4.60	
66	-0.32	4.60	
70	-0.29	4.61	
74	-0.32	4.60	
78	-0.35	4.68	
82	-0.39	4.72	-B+G
86	-0.43	4.68	
90	-0.66	4.80	
94	-1.00	5.22	
98	-0.83	6.00	
102	-0.55	6.50	
106	-0.53	6.25	
110	-0.09	6.35	+B+G

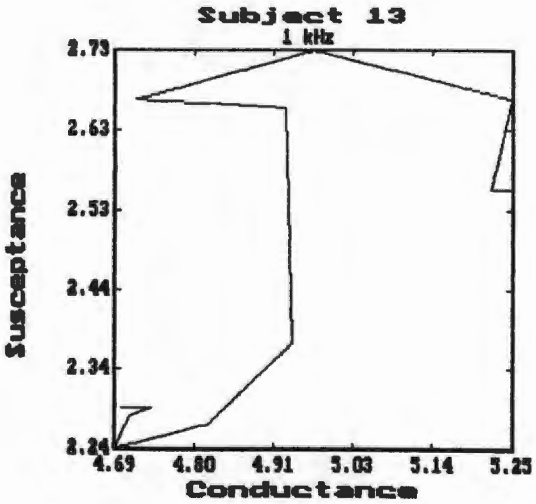
Subject 12 1 kHz

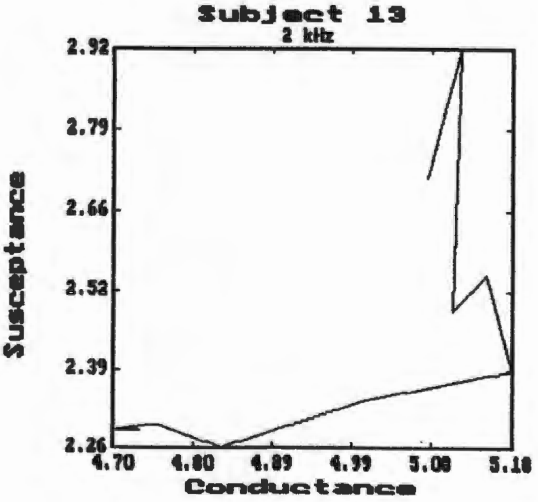
dB HL	Bm	Gm	Type
0	-0.30	4.60	
66	-0.25	4.68	
70	-0.37	4.76	
74	-0.37	4.63	
78	-0.40	4.74	
82	-0.39	4.68	
86	-0.42	4.63	
90	-1.12	5.03	-B+G
94	-0.99	5.72	
98	-0.69	6.52	
102	-0.34	6.20	
106	-0.21	6.59	D:B
110	-0.14	6.44	D:B

Subject 12 2 kHz

dB HL	Bm	Gm	Type
0	-0.30	4.60	
66	-0.30	4.60	
70	-0.30	4.60	
74	-0.30	4.60	
78	-0.37	4.60	
82	-0.39	4.60	
86	-0.63	4.58	
90	0.15	5.33	+B+G
94	0.54	6.24	
98	0.84	6.28	
102	1.00	6.23	
104	0.99	6.14	







Subject 13 0.5 kHz

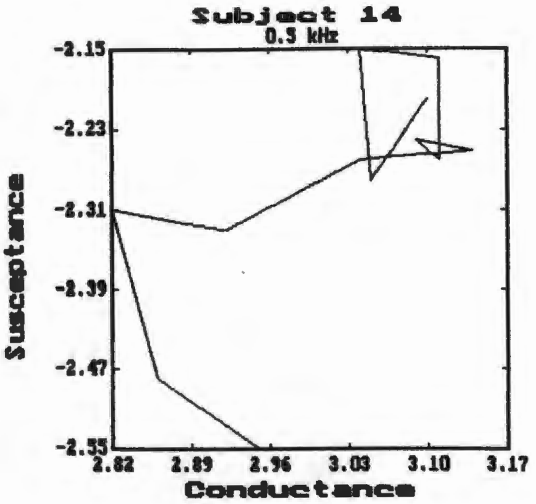
dB HL	Bm	Gm	Type
0	2.29	4.72	
66	2.29	4.72	
70	2.29	4.73	
74	2.27	4.73	
78	2.24	4.71	
82	2.31	4.78	
86	2.38	4.88	+B+G
90	2.43	4.94	
94	2.48	5.01	
98	2.57	4.96	
102	2.62	4.99	
106	2.59	4.91	
110	2.60	4.88	

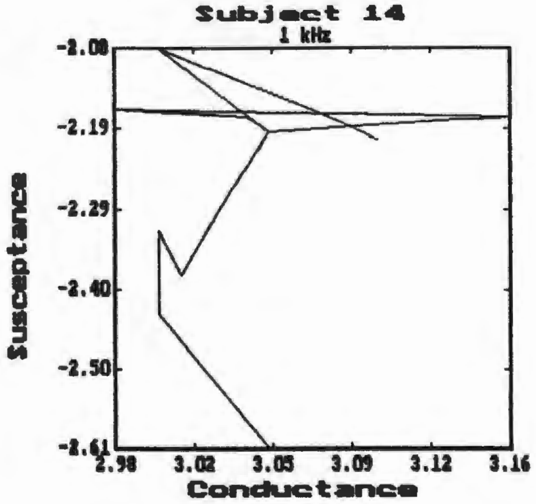
Subject 13 1 kHz

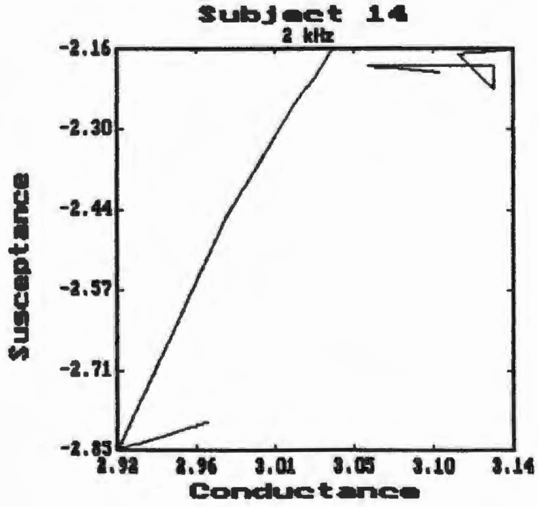
dB HL	Bm	Gm	Type
0	2.29	4.72	
66	2.29	4.70	
70	2.29	4.74	
74	2.28	4.71	
78	2.24	4.69	
82	2.27	4.82	
86	2.37	4.94	
90	2.66	4.93	+B+G
94	2.67	4.72	D:G
98	2.73	4.97	
102	2.67	5.25	
106	2.56	5.22	
110	2.56	5.25	

Subject 13 2 kHz

dB HL	Bm	Gm	Type
0	2.29	4.72	
66	2.29	4.72	
70	2.29	4.73	
74	2.29	4.70	
78	2.30	4.75	
82	2.26	4.83	
86	2.34	5.00	
90	2.39	5.18	+B+G
94	2.55	5.15	
98	2.49	5.11	
102	2.92	5.12	
104	2.71	5.08	







Subject 14 0.5 kHz

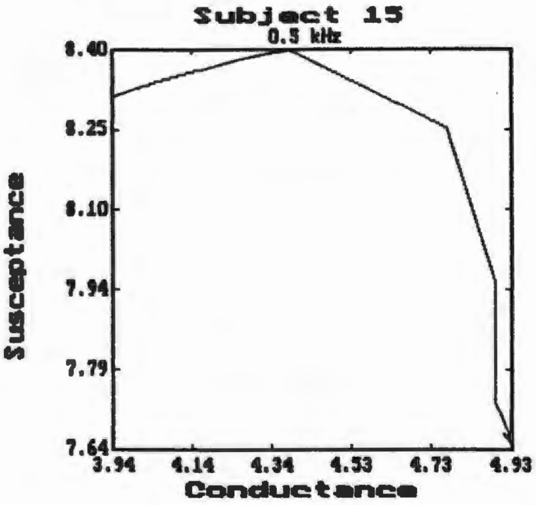
dB HL	Bm	Gm	Type
0	-2.20	3.10	
66	-2.28	3.05	
70	-2.15	3.04	
74	-2.16	3.11	
78	-2.26	3.11	
82	-2.24	3.09	
86	-2.25	3.14	
90	-2.26	3.04	
94	-2.33	2.92	-B-G
98	-2.31	2.82	
102	-2.48	2.86	
106	-2.55	2.95	
110	-2.55	3.17	D:G

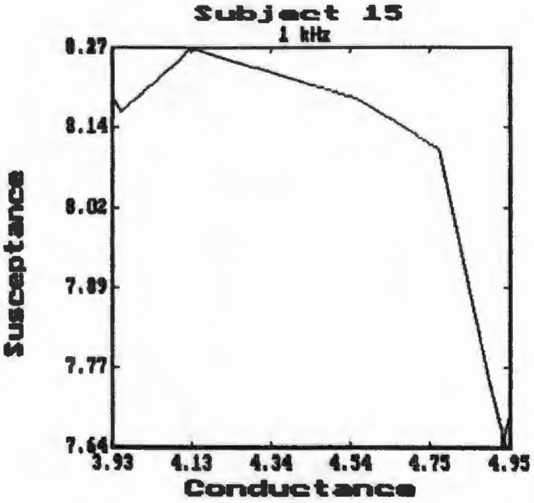
Subject 14 1 kHz

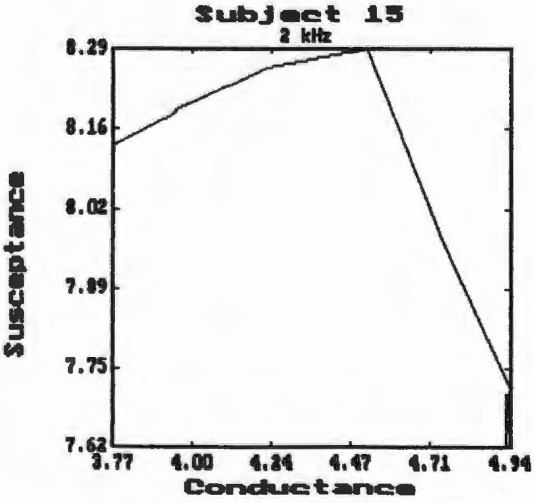
dB HL	Bm	Gm	Type
0	-2.20	3.10	
66	-2.16	3.07	
70	-2.08	3.00	
74	-2.19	3.05	
78	-2.17	3.16	
82	-2.16	2.98	
86	-2.17	3.04	
90	-2.19	3.05	
94	-2.28	3.03	
98	-2.38	3.01	-B-G
102	-2.32	3.00	
106	-2.43	3.00	
110	-2.61	3.05	

Subject 14 2 kHz

dB HL	Bm	Gm	Type
0	-2.20	3.10	
66	-2.19	3.06	
70	-2.19	3.13	
74	-2.23	3.13	
78	-2.17	3.11	
82	-2.16	3.14	
86	-2.16	3.04	
90	-2.21	3.03	
94	-2.25	3.02	
98	-2.45	2.98	-B-G
102	-2.85	2.92	
104	-2.80	2.97	







Subject 15 0.5 kHz

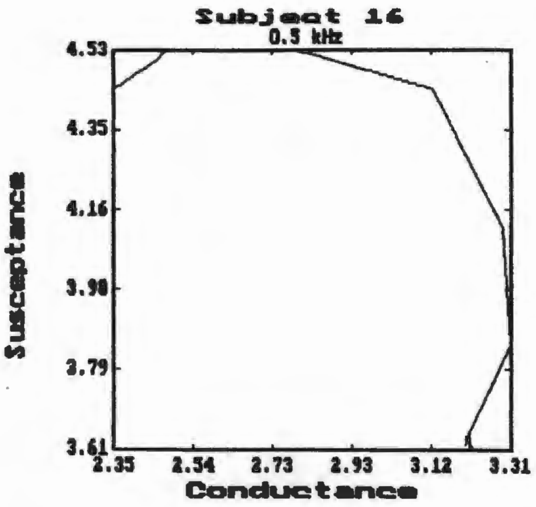
dB HL	Bm	Gm	Type
0	7.64	4.93	
66	7.69	4.95	
70	7.64	4.93	
74	7.67	4.93	
78	7.66	4.93	
82	7.64	4.94	
86	7.74	4.90	
90	8.11	4.77	+B-G
94	8.19	4.56	
98	8.27	4.13	
102	8.25	4.10	
106	8.17	3.95	
110	8.19	3.93	

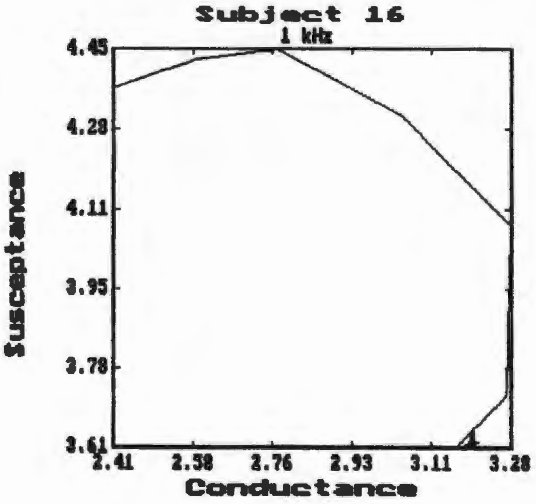
Subject 15 1 kHz

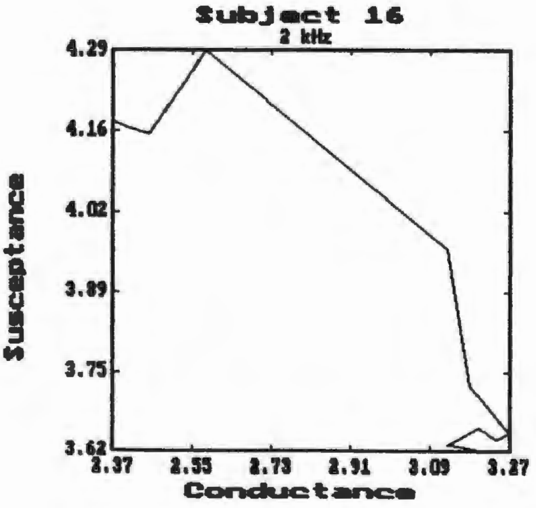
dB HL	Bm	Gm	Type
0	7.64	4.93	
66	7.69	4.95	
70	7.64	4.93	
74	7.67	4.93	
78	7.66	4.93	
82	7.64	4.94	
86	7.74	4.90	
90	8.11	4.77	+B-G
94	8.19	4.56	
98	8.27	4.13	
102	8.25	4.10	
106	8.17	3.95	
110	8.19	3.93	

Subject 15 2 kHz

dB HL	Bm	Gm	Type
0	7.64	4.93	
66	7.67	4.94	
70	7.71	4.93	
74	7.62	4.93	
78	7.66	4.93	
82	7.72	4.94	
86	7.96	4.75	+B-G
90	8.29	4.52	
94	8.26	4.23	
98	8.19	3.96	
102	8.18	3.94	
104	8.13	3.77	







Subject 16 0.5 kHz

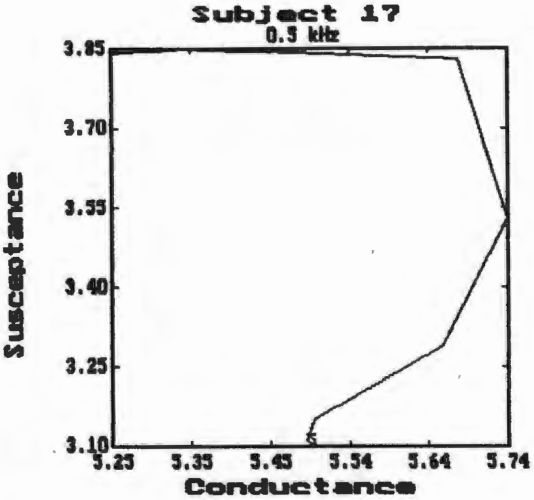
dB HL	Bm	Gm	Type
0	3.62	3.20	
66	3.64	3.20	
70	3.61	3.22	
74	3.61	3.21	
78	3.64	3.21	
82	3.63	3.20	
86	3.85	3.31	+B+G
90	4.12	3.29	
94	4.44	3.12	+B-G
98	4.53	2.79	
102	4.53	2.47	
106	4.51	2.46	
110	4.44	2.35	

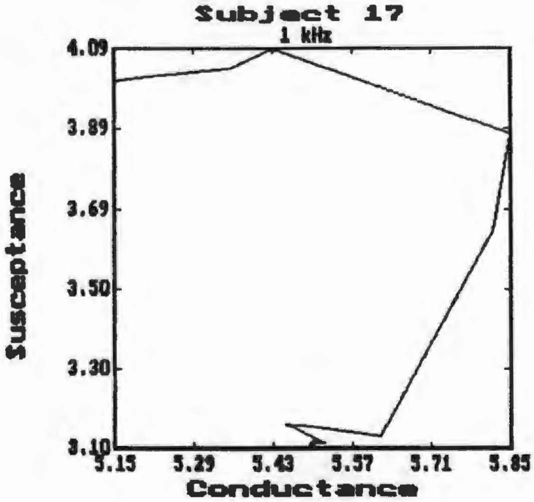
Subject 16 1 kHz

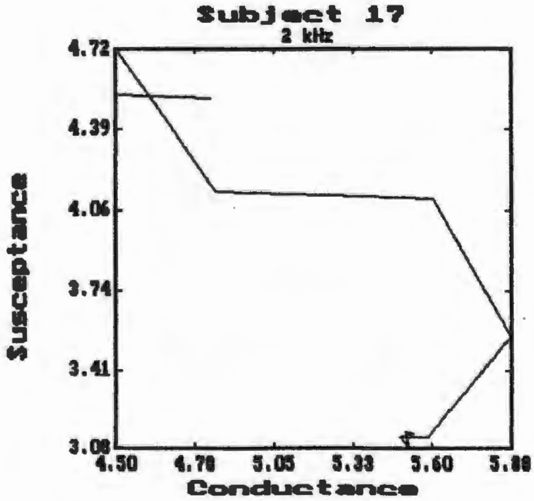
dB HL	Bm	Gm	Type
0	3.62	3.20	
66	3.65	3.20	
70	3.62	3.19	
74	3.62	3.20	
78	3.62	3.21	
82	3.61	3.16	
86	3.72	3.27	
90	4.08	3.28	
94	4.31	3.04	+B-G
98	4.45	2.77	
102	4.43	2.59	
106	4.39	2.47	
110	4.37	2.41	

Subject 16 2 kHz

dB HL	Bm	Gm	Type
0	3.62	3.20	
66	3.62	3.20	
70	3.63	3.13	
74	3.66	3.20	
78	3.64	3.24	
82	3.65	3.27	
86	3.73	3.18	
90	3.96	3.13	
94	4.29	2.58	+B-G
98	4.15	2.45	
102	4.16	2.41	
104	4.17	2.37	







Subject 17 0.5 kHz

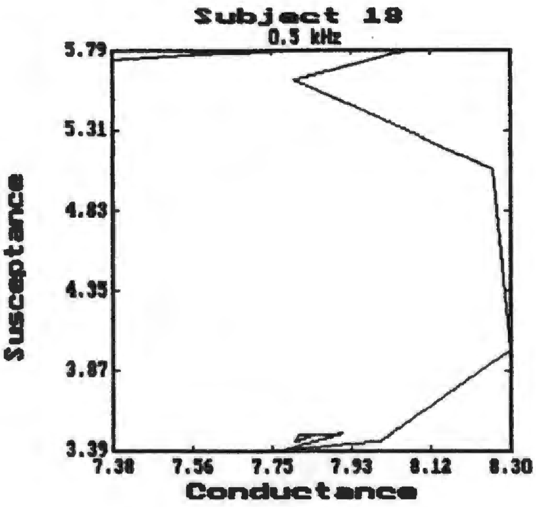
dB HL	Bm	Gm	Type
0	3.12	5.50	
66	3.12	5.49	
70	3.11	5.50	
74	3.11	5.50	
78	3.10	5.50	
82	3.11	5.49	
86	3.15	5.50	
90	3.29	5.66	+B+G
94	3.53	5.74	
98	3.83	5.68	
102	3.85	5.34	+B-G
106	3.84	5.25	
110	3.85	5.26	

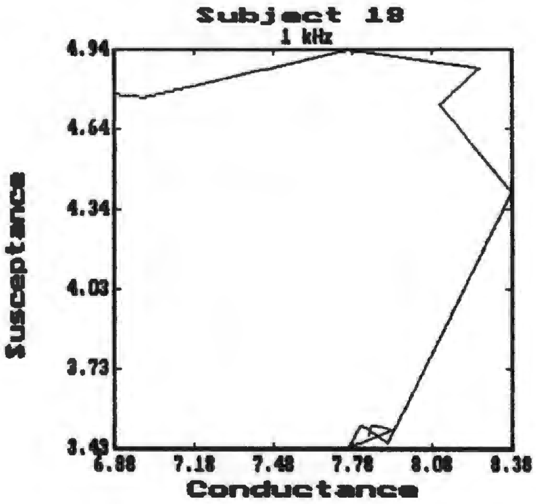
Subject 17 1 kHz

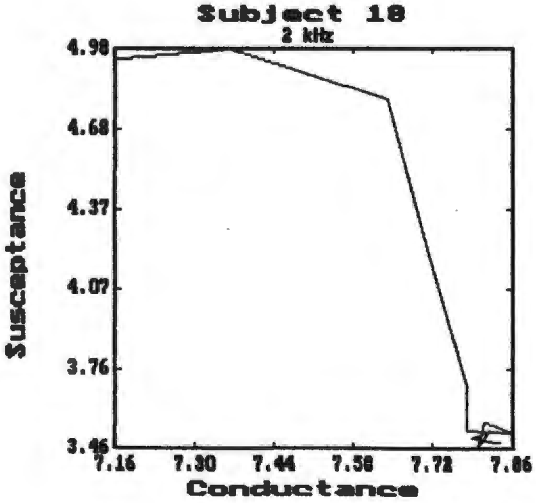
dB HL	Bm	Gm	Type
0	3.12	5.50	
66	3.10	5.49	
70	3.10	5.50	
74	3.11	5.50	
78	3.11	5.52	
82	3.16	5.45	
86	3.13	5.62	
90	3.64	5.82	+B+G
94	3.88	5.85	
98	4.09	5.43	D:G
102	4.04	5.35	D:G
106	4.02	5.19	D:G
110	4.01	5.15	+B-G

Subject 17 2 kHz

dB HL	Bm	Gm	Type
0	3.12	5.50	
66	3.08	5.52	
70	3.15	5.51	
74	3.14	5.54	
78	3.13	5.49	
82	3.13	5.59	
86	3.55	5.88	+B+G
90	4.11	5.61	D:G
94	4.14	4.85	+B-G
98	4.72	4.50	
102	4.53	4.50	
104	4.52	4.83	







Subject 18 0.5 kHz

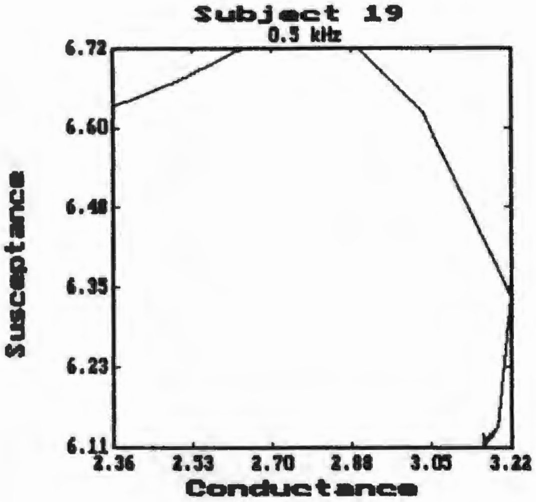
dB HL	Bm	Gm	Type
0	3.48	7.84	
66	3.44	7.80	
70	3.48	7.81	
74	3.48	7.86	
78	3.49	7.91	
82	3.39	7.77	
86	3.45	8.00	+B+G
90	4.00	8.30	
94	5.08	8.26	
98	5.61	7.80	D:G
102	5.79	8.06	D:G
106	5.79	7.76	D:G
110	5.73	7.38	+B-G

Subject 18 1 kHz

dB HL	Bm	Gm	Type
0	3.48	7.84	
66	3.52	7.85	
70	3.50	7.93	
74	3.43	7.76	
78	3.52	7.81	
82	3.45	7.91	
86	3.87	8.12	+B+G
90	4.40	8.38	
94	4.73	8.11	
98	4.87	8.26	
102	4.94	7.76	+B-G
106	4.76	6.99	
110	4.77	6.88	

Subject 18 2 kHz

dB HL	Bm	Gm	Type
0	3.48	7.84	
66	3.50	7.79	
70	3.53	7.82	
74	3.46	7.80	
78	3.56	7.81	
82	3.52	7.86	
86	3.53	7.78	
90	3.70	7.78	
94	4.22	7.71	+B-G
98	4.79	7.64	
102	4.98	7.36	
104	4.94	7.16	

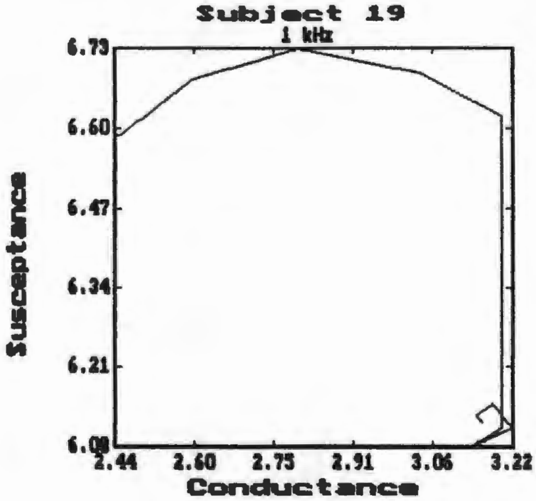


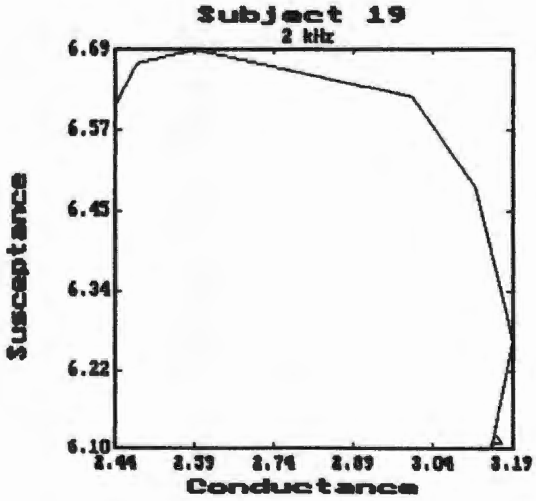
Subject 19 0.5 kHz

dB HL	Bm	Gm	Type
0	6.12	3.16	
66	6.13	3.16	
70	6.11	3.16	
74	6.12	3.16	
78	6.14	3.19	
82	6.11	3.16	
86	6.14	3.19	
90	6.34	3.22	
94	6.62	3.03	+B-G
98	6.72	2.89	
102	6.72	2.64	
106	6.67	2.50	
110	6.63	2.36	

Subject 19 1 kHz

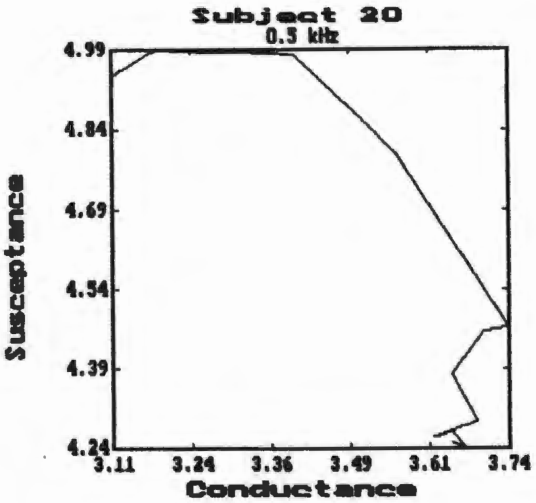
dB HL	Bm	Gm	Type
0	6.12	3.16	
66	6.13	3.15	
70	6.15	3.18	
74	6.11	3.22	
78	6.08	3.14	
82	6.11	3.20	
86	6.37	3.20	
90	6.62	3.20	
94	6.69	3.04	+B-G
98	6.73	2.80	
102	6.68	2.59	
106	6.59	2.45	
110	6.59	2.44	





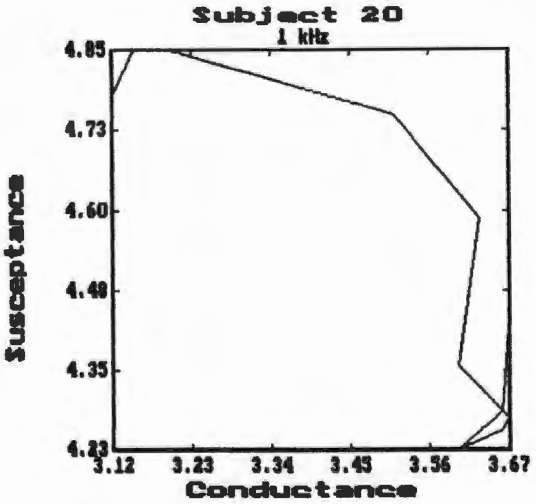
Subject 19 2 kHz

dB HL	Bm	Gm	Type
0	6.12	3.16	
66	6.12	3.16	
70	6.11	3.17	
74	6.11	3.16	
78	6.10	3.15	
82	6.26	3.19	
86	6.30	3.18	
90	6.49	3.12	
94	6.62	3.00	+B-G
98	6.69	2.59	
102	6.67	2.48	
104	6.61	2.44	



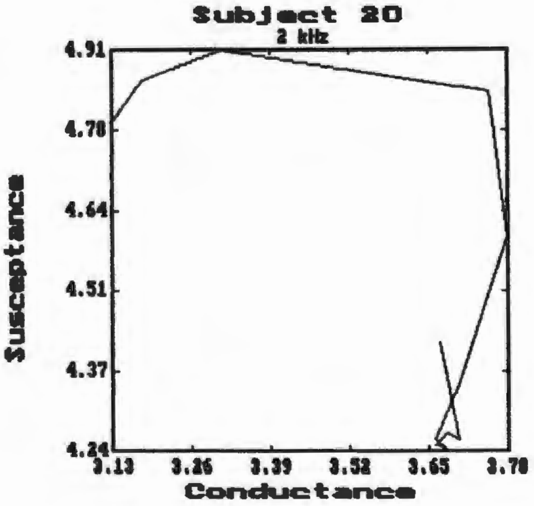
Subject 20 0.5 kHz

dB HL	Bm	Gm	Type
0	4.24	3.67	
66	4.25	3.65	
70	4.24	6.67	
74	4.27	3.65	
78	4.26	3.62	
82	4.29	3.69	
86	4.38	3.65	
90	4.46	3.70	
94	4.47	3.74	
98	4.80	3.56	+B-G
102	4.98	3.40	
106	4.99	3.18	
110	4.94	3.11	



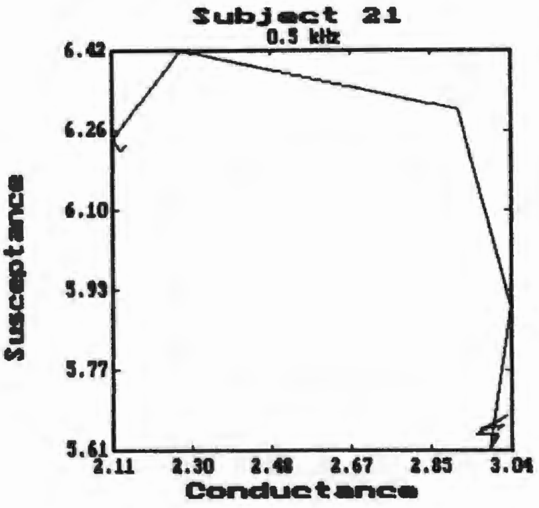
Subject 20 1 kHz

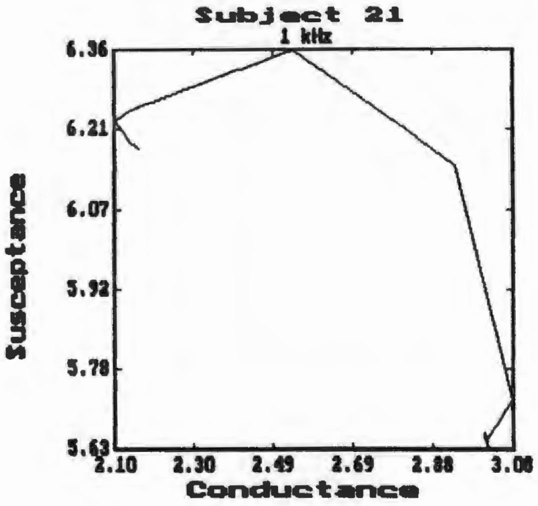
dB HL	Bm	Gm	Type
0	4.42	3.67	
66	4.29	3.66	
70	4.25	3.62	
74	4.23	3.60	
78	4.26	3.66	
82	4.26	3.66	
86	4.28	3.67	
90	4.36	3.60	
94	4.59	3.63	
98	4.75	3.51	+B-G
102	4.85	3.20	
106	4.85	3.15	
110	4.78	3.12	

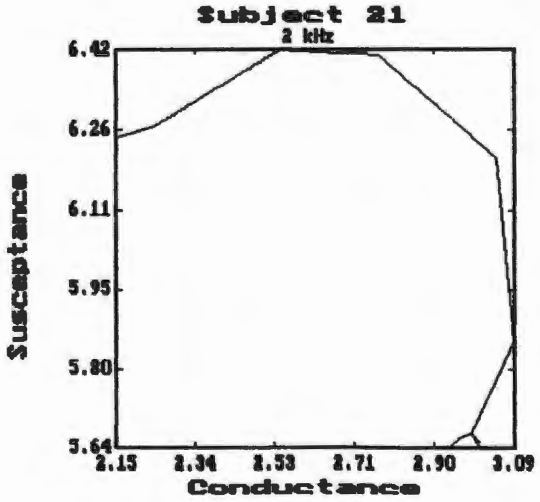


Subject 20 2 kHz

dB HL	Bm	Gm	Type
0	4.42	3.67	
66	4.26	3.70	
70	4.27	3.68	
74	4.25	3.66	
78	4.24	3.68	
82	4.26	3.66	
86	4.35	3.70	
90	4.60	3.78	+B+G
94	4.84	3.75	
98	4.91	3.31	+B-G
102	4.86	3.18	
104	4.79	3.13	







Subject 21 0.5 kHz

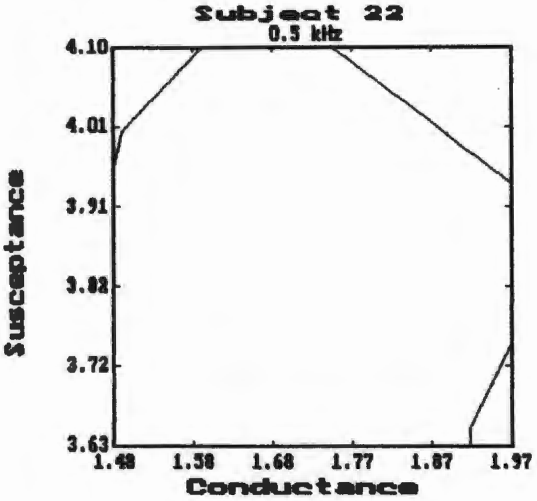
dB HL	Bm	Gm	Type
0	5.65	3.01	
66	5.66	3.02	
70	5.65	2.97	
74	5.68	3.03	
78	5.64	2.96	
82	5.64	3.01	
86	5.61	2.99	
90	5.90	3.04	
94	6.30	2.92	+B-G
98	6.42	2.27	
102	6.24	2.11	
106	6.22	2.13	
110	6.23	2.14	

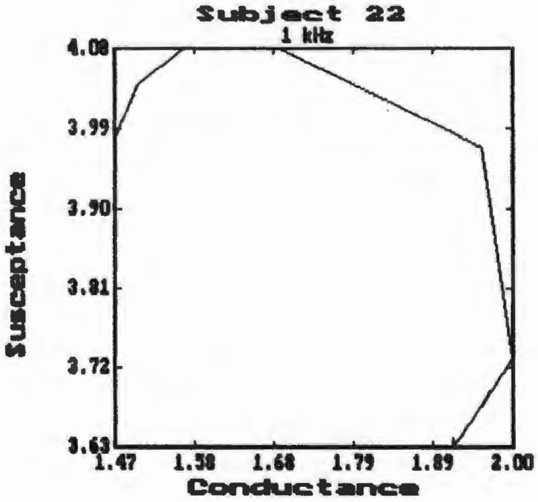
Subject 21 1 kHz

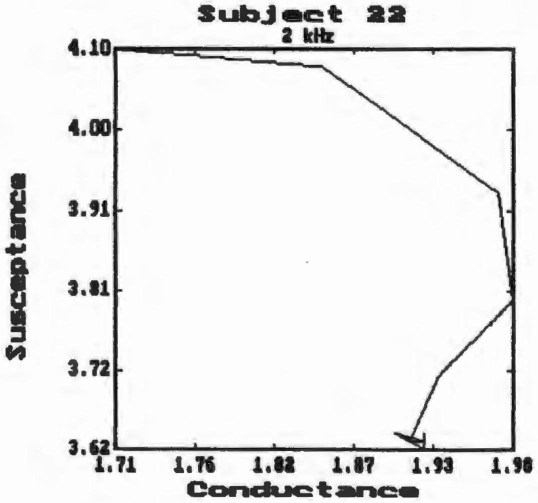
dB HL	Bm	Gm	Type
0	5.65	3.01	
66	5.65	3.01	
70	5.66	3.01	
74	5.63	3.02	
78	5.65	3.01	
82	5.65	3.02	
86	5.72	3.08	
90	6.15	2.94	
94	6.36	2.54	+B-G
98	6.25	2.14	
102	6.23	2.10	
106	6.19	2.14	
110	6.18	2.16	

Subject 21 2 kHz

dB HL	Bm	Gm	Type
0	5.65	3.01	
66	5.67	2.99	
70	5.66	2.96	
74	5.64	2.94	
78	5.64	3.01	
82	5.67	2.99	
86	5.85	3.09	
90	6.21	3.05	
94	6.41	2.77	+B-G
98	6.42	2.54	
102	6.27	2.24	
104	6.25	2.15	


Subject 22
0.5 kHz


Subject 22
1 kHz


Subject 22
2 kHz

Subject 22 0.5 kHz

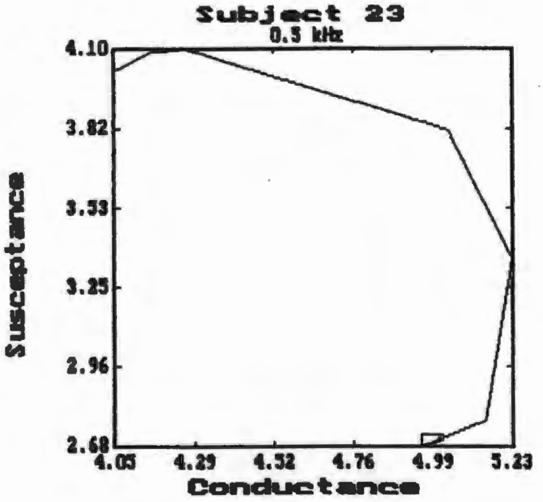
dB HL	Bm	Gm	Type
0	3.63	1.92	
66	3.63	1.92	
70	3.63	1.92	
74	3.63	1.92	
78	3.63	1.92	
82	3.65	1.92	
86	3.75	1.97	
90	3.94	1.97	
94	4.10	1.75	+B-G
98	4.10	1.59	
102	4.02	1.51	
106	4.00	1.49	
110	3.96	1.48	

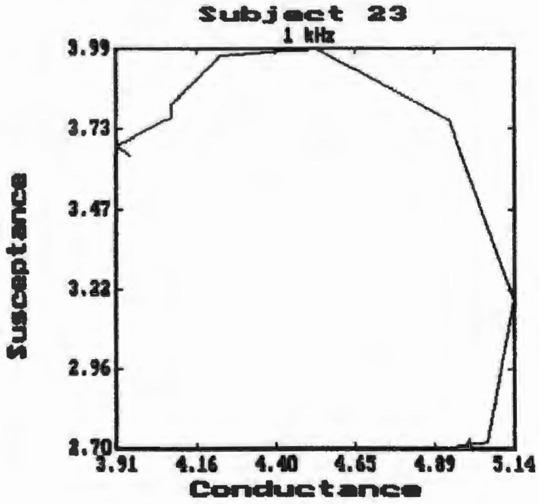
Subject 22 1 kHz

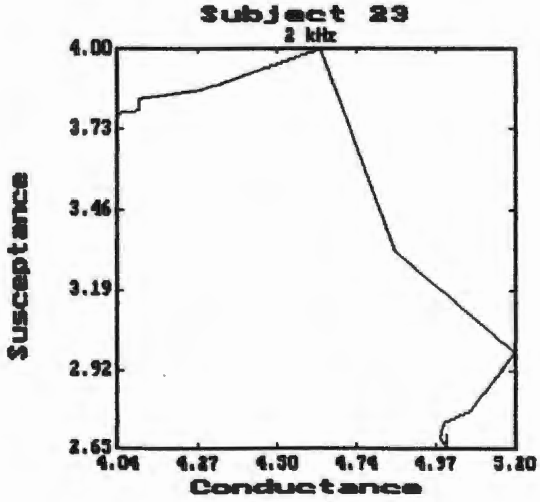
dB HL	Bm	Gm	Type
0	3.63	1.92	
66	3.64	1.92	
70	3.63	1.92	
74	3.63	1.92	
78	3.63	1.92	
82	3.63	1.92	
86	3.64	1.93	
90	3.73	2.00	
94	3.97	1.96	
98	4.08	1.69	+B-G
102	4.08	1.56	
106	4.04	1.50	
110	3.98	1.47	

Subject 22 2 kHz

dB HL	Bm	Gm	Type
0	3.63	1.92	
66	3.64	1.92	
70	3.62	1.92	
74	3.64	1.90	
78	3.63	1.92	
82	3.63	1.91	
86	3.67	1.92	
90	3.71	1.93	
94	3.80	1.98	
98	3.93	1.97	+B+G
102	4.08	1.85	+B-G
104	4.10	1.71	







Subject 23 0.5 kHz

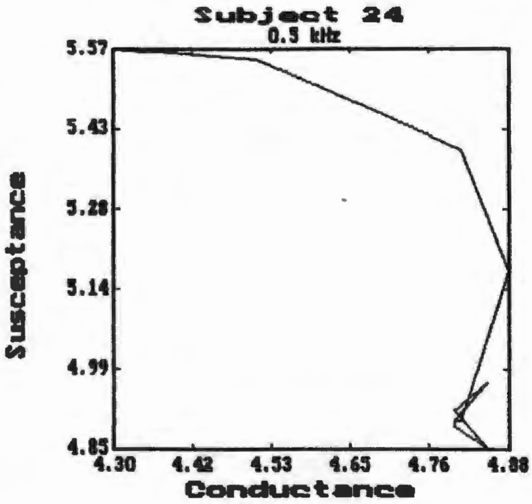
dB HL	Bm	Gm	Type
0	2.70	5.00	
66	2.72	5.02	
70	2.72	4.96	
74	2.68	4.96	
78	2.70	5.02	
82	2.69	4.99	
86	2.77	5.15	
90	3.35	5.23	+B+G
94	3.81	5.04	D:G
98	3.97	4.60	+B-G
102	4.10	4.26	
106	4.09	4.16	
110	4.02	4.05	

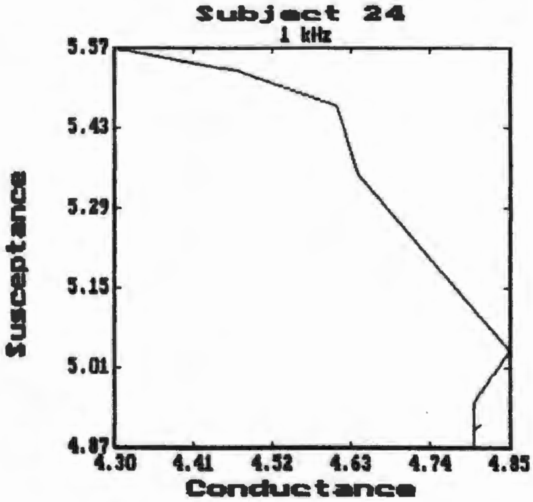
Subject 23 1 kHz

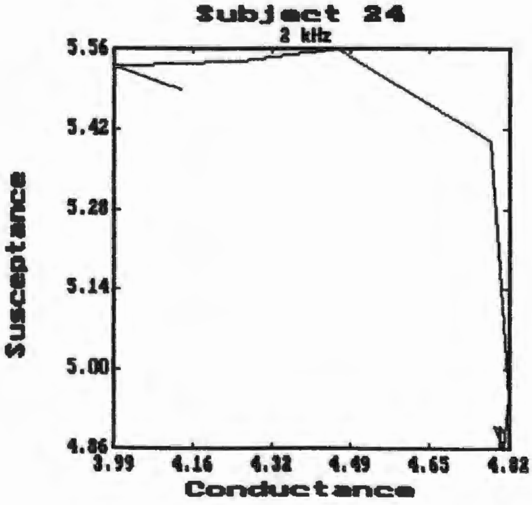
dB HL	Bm	Gm	Type
0	2.70	5.00	
66	2.73	5.00	
70	2.70	4.99	
74	2.70	4.93	
78	2.72	5.06	
82	3.18	5.14	+B+G
86	3.76	4.94	D:G
90	3.99	4.53	+B-G
94	3.97	4.23	
98	3.81	4.08	
102	3.77	4.08	
106	3.68	3.91	
110	3.65	3.95	

Subject 23 2 kHz

dB HL	Bm	Gm	Type
0	2.70	5.00	
66	2.65	5.00	
70	2.69	4.98	
74	2.74	4.99	
78	2.78	5.07	
82	2.98	5.20	+B+G
86	3.32	4.85	
90	4.00	4.63	D:G
94	3.86	4.28	+B-G
98	3.83	4.10	
102	3.79	4.10	
104	3.78	4.04	







Subject 24 0.5 kHz

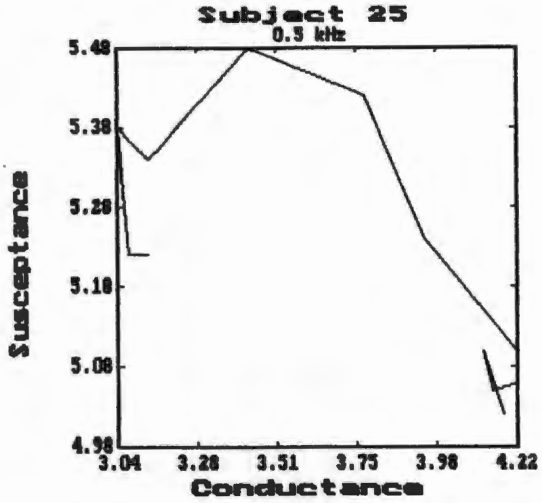
dB HL	Bm	Gm	Type
0	4.90	4.80	
66	4.90	4.80	
70	4.97	4.85	
74	4.92	4.80	
78	4.85	4.85	
82	4.89	4.80	
86	4.90	4.80	
90	4.90	4.80	
94	4.90	4.81	
98	5.17	4.88	
102	5.39	4.81	
106	5.55	4.51	+B-G
110	5.57	4.30	

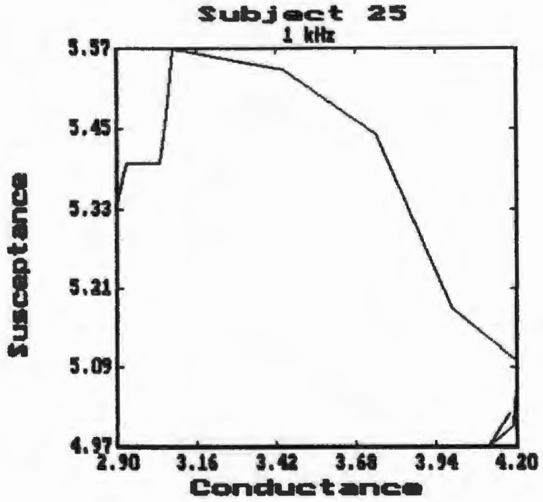
Subject 24 1 kHz

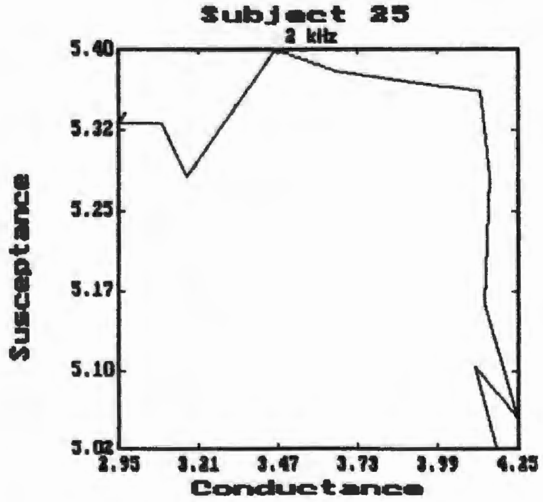
dB HL	Bm	Gm	Type
0	4.90	4.80	
66	4.90	4.80	
70	4.91	4.81	
74	4.91	4.81	
78	4.90	4.80	
82	4.90	4.80	
86	4.87	4.80	
90	4.95	4.80	
94	5.04	4.85	
98	5.35	4.64	+B-G
102	5.47	4.61	
106	5.53	4.47	
110	5.57	4.30	

Subject 24 2 kHz

dB HL	Bm	Gm	Type
0	4.90	4.80	
66	4.86	4.80	
70	4.90	4.80	
74	4.89	4.81	
78	4.90	4.79	
82	4.86	4.81	
86	4.95	4.82	
90	5.40	4.78	
94	5.56	4.46	+B-G
98	5.54	4.26	
102	5.53	3.99	
104	5.49	4.13	







Subject 25 0.5 kHz

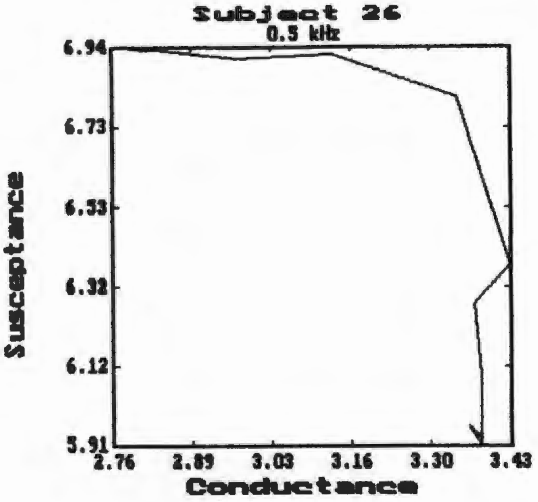
dB HL	Bm	Gm	Type
0	5.02	4.18	
66	5.10	4.12	
70	5.05	4.15	
74	5.06	4.22	
78	4.98	4.22	
82	5.10	4.22	
86	5.24	3.95	+B-G
90	5.42	3.77	
94	5.48	3.43	
98	5.34	3.13	
102	5.38	3.04	
106	5.22	3.07	
110	5.22	3.13	

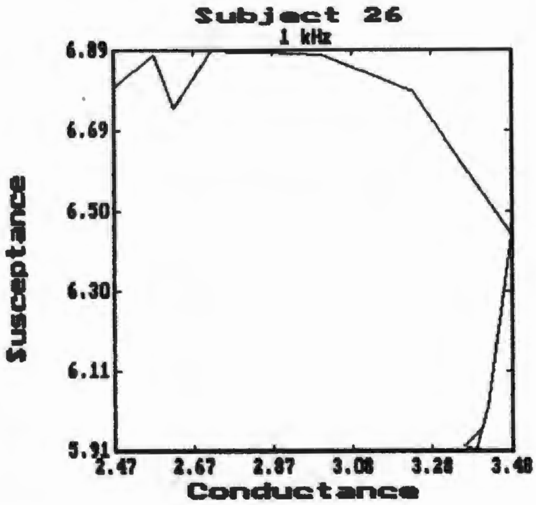
Subject 25 1 kHz

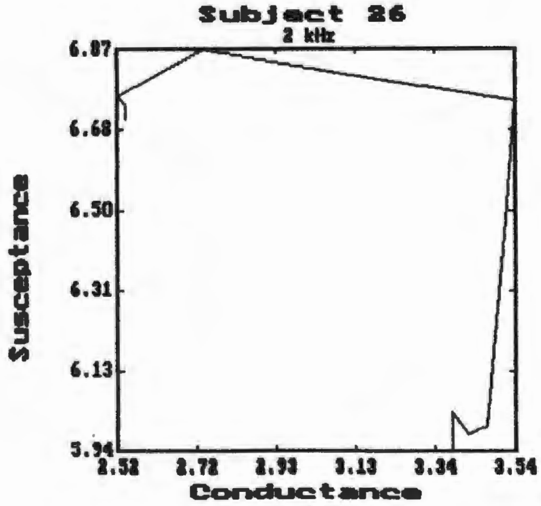
dB HL	Bm	Gm	Type
0	5.02	4.18	
66	4.97	4.11	
70	5.00	4.19	
74	5.06	4.20	
78	5.10	4.20	
82	5.18	3.99	+B-G
86	5.44	3.75	
90	5.54	3.44	
94	5.57	3.08	
98	5.47	3.06	
102	5.40	3.04	
106	5.40	2.93	
110	5.34	2.90	

Subject 25 2 kHz

dB HL	Bm	Gm	Type
0	5.02	4.18	
66	5.10	4.11	
70	5.05	4.25	
74	5.16	4.14	
78	5.28	4.16	
82	5.36	4.13	
86	5.38	3.66	+B-G
90	5.40	3.46	
94	5.28	3.17	
98	5.33	3.09	
102	5.33	2.95	
104	5.34	2.97	







Subject 26 0.5 kHz

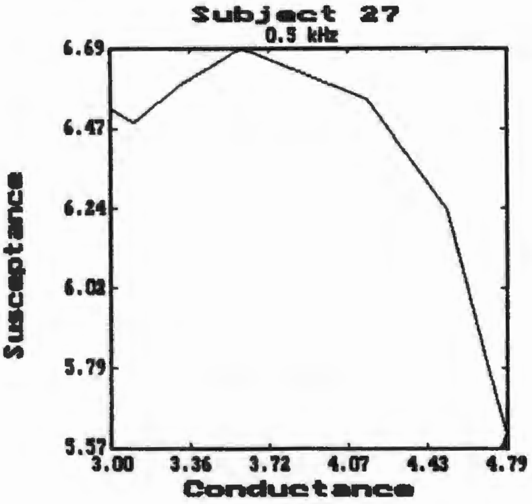
dB HL	Bm	Gm	Type
0	5.94	3.38	
66	5.93	3.38	
70	5.96	3.36	
74	5.91	3.38	
78	5.94	3.38	
82	6.09	3.38	
86	6.28	3.37	
90	6.38	3.43	+B+G
94	6.81	3.34	+B-G
98	6.92	3.13	
102	6.91	2.97	
106	6.94	2.78	
110	6.94	2.76	

Subject 26 1 kHz

dB HL	Bm	Gm	Type
0	5.94	3.38	
66	5.94	3.38	
70	5.96	3.40	
74	5.92	3.36	
78	5.91	3.39	
82	6.02	3.42	
86	6.44	3.48	+B+G
90	6.79	3.23	+B-G
94	6.88	3.00	
98	6.89	2.72	
102	6.75	2.62	
106	6.88	2.57	
110	6.80	2.47	

Subject 26 2 kHz

dB HL	Bm	Gm	Type
0	5.94	3.38	
66	5.98	3.38	
70	6.03	3.38	
74	5.98	3.42	
78	6.00	3.47	
82	6.51	3.52	+B+G
86	6.75	3.54	
90	6.82	3.05	+B-G
94	6.87	2.74	
98	6.76	2.52	
102	6.74	2.54	
104	6.71	2.54	

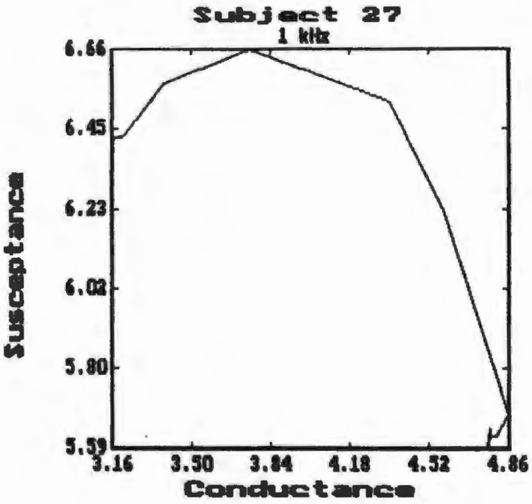


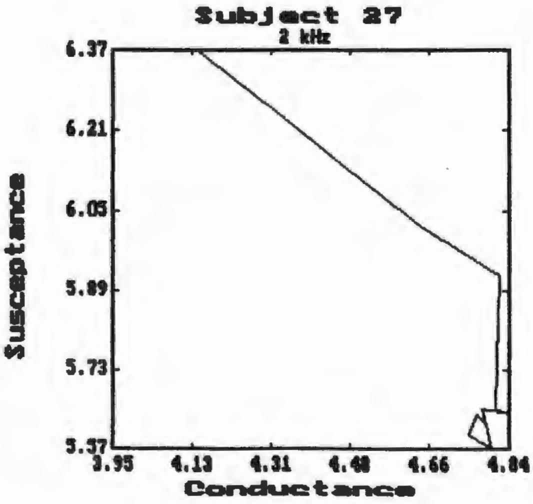
Subject 27 0.5 kHz

dB HL	Bm	Gm	Type
0	5.62	4.79	
66	5.62	4.79	
70	5.57	4.78	
74	5.57	4.76	
78	5.57	4.76	
82	5.61	4.79	
86	5.78	4.71	
90	6.24	4.52	+B-G
94	6.55	4.16	
98	6.69	3.59	
102	6.59	3.32	
106	6.48	3.10	
110	6.52	3.00	

Subject 27 1 kHz

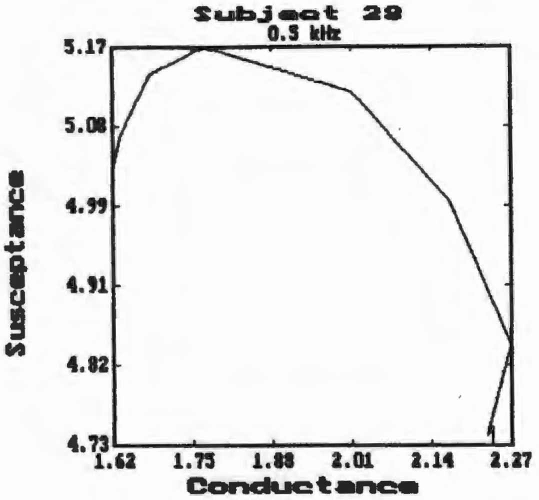
dB HL	Bm	Gm	Type
0	5.62	4.79	
66	5.62	4.78	
70	5.64	4.78	
74	5.59	4.77	
78	5.62	4.78	
82	5.62	4.81	
86	5.68	4.86	
90	6.23	4.58	+B-G
94	6.52	4.35	
98	6.66	3.75	
102	6.57	3.38	
106	6.43	3.21	
110	6.42	3.16	

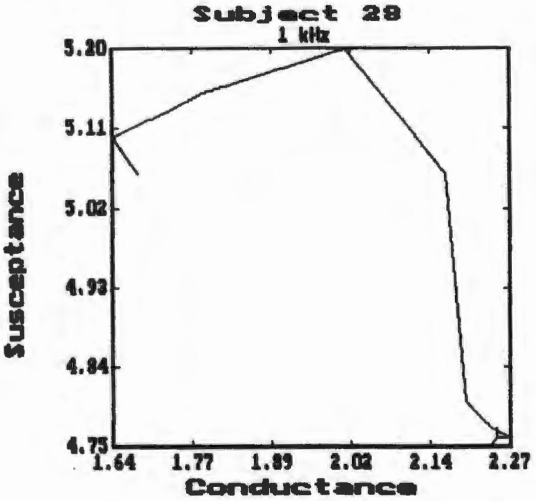


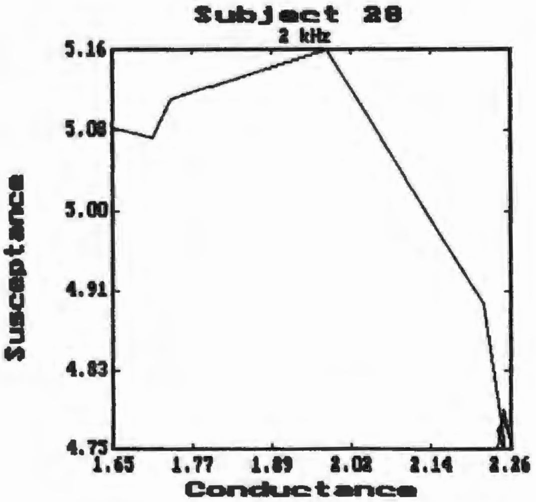


Subject 27 2 kHz

dB HL	Bm	Gm	Type
0	5.62	4.79	
66	5.64	4.77	
70	5.60	4.75	
74	5.57	4.80	
78	5.62	4.79	
82	5.65	4.78	
86	5.64	4.84	
90	5.65	4.81	
94	5.92	4.82	
98	6.02	4.64	+B-G
102	6.37	4.14	
104	6.37	3.95	







Subject 28 0.5 kHz

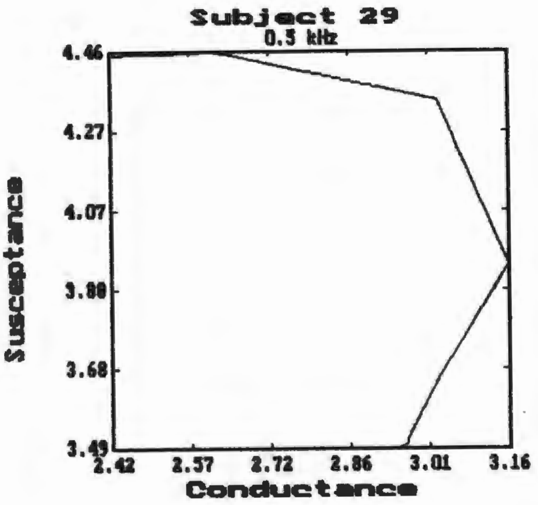
dB HL	Bm	Gm	Type
0	4.75	2.24	
66	4.74	2.24	
70	4.73	2.24	
74	4.75	2.24	
78	4.74	2.23	
82	4.74	2.23	
86	4.84	2.27	
90	5.00	2.17	
94	5.12	2.01	+B-G
98	5.17	1.77	
102	5.14	1.68	
106	5.07	1.63	
110	5.04	1.62	

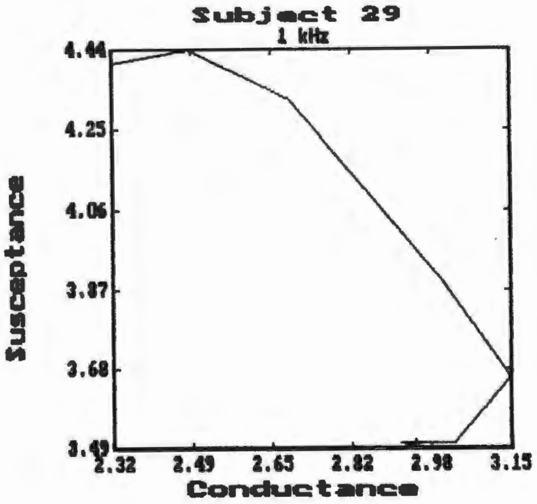
Subject 28 1 kHz

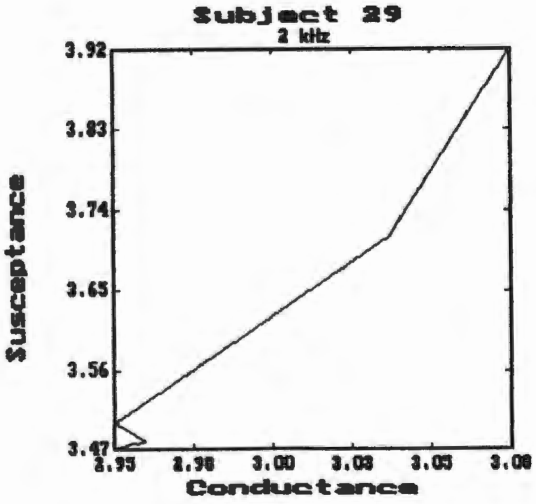
dB HL	Bm	Gm	Type
0	4.75	2.24	
66	4.76	2.25	
70	4.77	2.25	
74	4.76	2.25	
78	4.76	2.27	
82	4.77	2.24	
86	4.80	2.20	
90	5.06	2.17	
94	5.20	2.01	+B-G
98	5.15	1.78	
102	5.13	1.73	
106	5.10	1.64	
110	5.06	1.68	

Subject 28 2 kHz

dB HL	Bm	Gm	Type
0	4.75	2.24	
66	4.79	2.25	
70	4.76	2.26	
74	4.78	2.25	
78	4.77	2.24	
82	4.75	2.25	
86	4.76	2.25	
90	4.90	2.22	
94	5.16	1.98	+B-G
98	5.11	1.74	
102	5.07	1.71	
104	5.08	1.65	







Subject 29 0.5 kHz

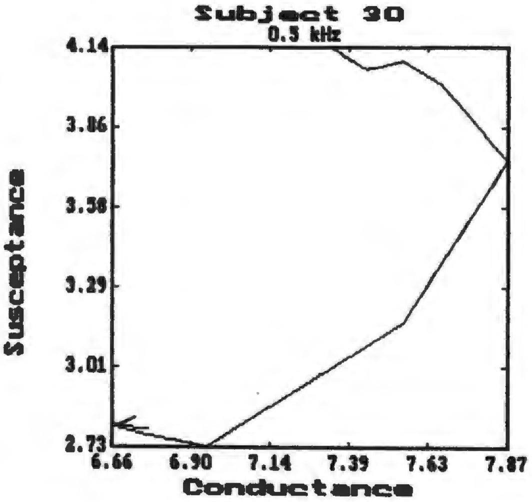
dB HL	Bm	Gm	Type
0	3.49	2.95	
66	3.49	2.94	
70	3.49	2.96	
74	3.49	2.95	
78	3.49	2.95	
82	3.49	2.95	
86	3.50	2.97	
90	3.51	2.97	
94	3.66	3.03	
98	3.94	3.16	+B+G
102	4.34	3.03	D:G
106	4.46	2.61	+B-G
110	4.45	2.42	

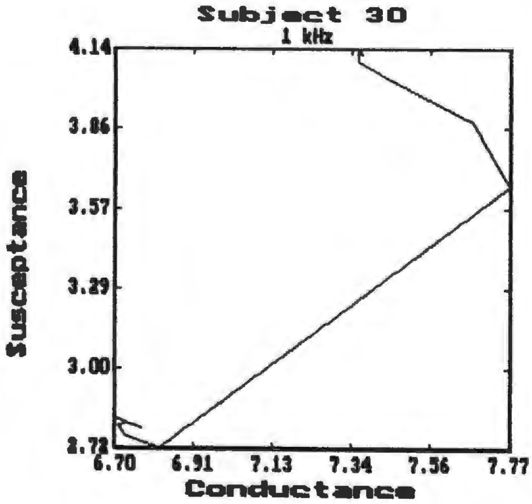
Subject 29 1 kHz

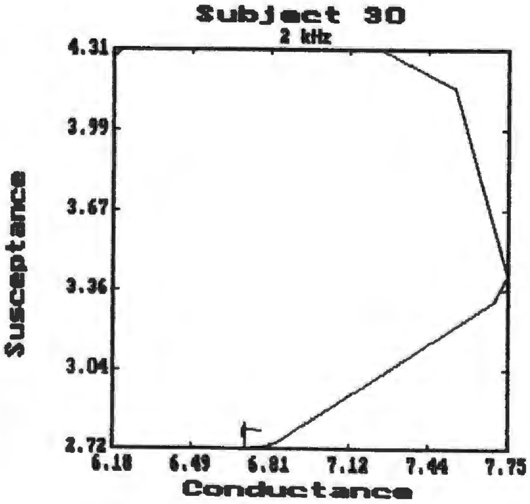
dB HL	Bm	Gm	Type
0	3.49	2.95	
66	3.49	2.95	
70	3.51	2.95	
74	3.49	2.94	
78	3.50	2.94	
82	3.49	2.97	
86	3.50	2.92	
90	3.50	3.03	
94	3.66	3.15	+B+G
98	3.89	3.01	D:G
102	4.32	2.69	+B-G
106	4.44	2.48	
110	4.41	2.32	

Subject 29 2 kHz

dB HL	Bm	Gm	Type
0	3.49	2.95	
66	3.49	2.95	
70	3.49	2.95	
74	3.50	2.95	
78	3.50	2.95	
82	3.52	2.95	
86	3.47	2.95	
90	3.48	2.96	
94	3.50	2.95	
98	3.71	3.04	+B+G
102	3.92	3.08	D:G
104	3.82	3.08	







Subject 30 0.5 kHz

dB HL	Bm	Gm	Type
0	2.79	6.77	
66	2.80	6.68	
70	2.83	6.73	
74	2.80	6.66	
78	2.77	6.76	
82	2.73	6.95	
86	3.17	7.55	+B+G
90	3.74	7.87	
94	4.01	7.67	
98	4.09	7.55	
102	4.06	7.44	
106	4.14	7.33	
110	4.09	7.39	

Subject 30 1 kHz

dB HL	Bm	Gm	Type
0	2.79	6.77	
66	2.83	6.70	
70	2.81	6.73	
74	2.80	6.71	
78	2.76	6.73	
82	2.72	6.82	
86	3.19	7.30	+B+G
90	3.65	7.77	
94	3.88	7.67	
98	4.04	7.43	
102	4.10	7.36	
106	4.14	7.36	
110	4.12	7.37	

Subject 30 2 kHz

dB HL	Bm	Gm	Type
0	2.79	6.77	
66	2.80	6.70	
70	2.77	6.70	
74	2.82	6.71	
78	2.72	6.71	
82	2.73	6.81	
86	3.31	7.70	+B+G
90	3.41	7.75	
94	4.16	7.54	
98	4.31	7.25	D:G
102	4.31	6.21	+B-G
104	4.28	6.18	

APPENDIX F

Diphasic Reflex Patterns recorded in Part Two.

Values of the Central Extrema are presented
as Zeroed Susceptance or Conductance Values
both at Tympanometric Peak Pressure
and at +200 daPa.

DIPHASIC REFLEXES RECORDED FOR PART TWO FOR THE 1000 Hz PROBE FREQUENCY. THE EFFECT OF ADDING +200 daPa TO THE EXTERNAL AUDITORY MEATUS ON THE CENTRAL EXTREMUM OF THE REFLEX IS ALSO SHOWN

Subject	Component B/G	Stimulus Frequency	Intensity	Central Extremum at tympanometric peak: zeroed values	Central Extremum at +200 daPa: zeroed values
		kHz	dB HL	mmho	mmho
1	G	0.5	102	0.15	-0.09
1	G	1	98	0.35	-0.09
1	G	1	102	-0.04	-0.10
1	G	2	98	-0.24	-0.10
2	G	2	98	0.06	-0.16
4	G	0.5	102	0.00	-0.04
4	B	1	102	0.18	0.03
4	B	2	102	0.02	0.03
6	G	0.5	102	0.01	-0.05
6	G	2	102	-0.02	-0.18
9	G	0.5	106	0.03	-0.03
9	G	0.5	110	0.05	-0.03
9	B	1	98	-0.18	0.02
9	B	1	102	-0.25	0.02
9	B	1	106	-0.31	0.02
9	B	1	110	-0.32	0.02
9	G	2	104	0.35	-0.04
10	G	0.5	110	0.09	0.07
11	G	1	106	0.24	-0.03
12	B	1	106	-0.27	0.15
12	B	1	110	-0.30	0.11
13	G	1	94	0.00	-0.04
14	G	0.5	110	0.03	-0.04
17	G	1	98	-0.07	-0.09
17	G	1	102	-0.15	-0.09
17	G	1	106	-0.31	-0.09
17	G	2	90	0.11	-0.15
18	G	0.5	98	0.22	-0.05
18	G	0.5	102	-0.04	-0.05
18	G	0.5	106	-0.08	-0.06
23	G	0.5	94	0.04	-0.05
23	G	1	86	-0.06	-0.05
23	G	2	90	0.37	-0.15
29	G	0.5	102	0.08	-0.07
29	G	2	102	0.13	-0.07
30	G	2	106	0.46	-0.20

APPENDIX G

Natural Frequency used to approximate Resonant Frequency for each of the 30 Ears used in Part Two and the Measured Susceptance and Conductance Values with and without the Acoustic Reflex at each Subject's Resonant Frequency.

REFLEX PATTERNS RECORDED AT EACH INDIVIDUAL'S RESONANT FREQUENCY USING A TYMPANOMETRIC APPROACH

Ss	Resonant Frequency Hz	Bm without the reflex mmho	Bm with the reflex mmho	Gm without the reflex mmho	Gm with the reflex mmho
1	950	2.47	3.95	4.85	6.41
2	750	3.48	3.65	5.64	5.64
3	900	2.50	2.64	5.50	6.17
4	700	1.53	1.94	4.00	4.25
5	650	NOT TESTED		NOT TESTED	
6	950	5.42	6.02	4.82	4.93
7	500	2.12	2.41	5.69	5.96
8	650	2.92	3.06	5.08	5.42
9	450	0.25	1.17	10.89	11.74
10	800	2.54	2.86	3.35	3.44
11	700	0.67	0.80	5.36	5.64
12	700	2.00	2.60	7.20	7.50
13	850	2.93	3.01	5.69	5.77
14	750	1.15	2.48	6.52	7.60
15	1150	7.20	7.42	7.63	8.58
16	1050	3.49	4.18	3.52	3.73
17	900	4.05	4.59	5.88	6.28
18	1000	2.59	2.90	8.10	8.92
19	1150	6.65	7.62	5.28	5.61
20	1050	3.61	4.17	4.03	4.14
21	1400	5.69	5.78	5.26	5.87
22	1300	4.51	4.77	2.64	2.73
23	1050	2.55	3.49	4.93	5.65
24	1050	4.10	4.71	5.46	5.72
25	1150	4.08	4.76	5.17	5.30
26	1300	7.51	7.78	3.52	4.08
27	1100	5.04	5.85	4.62	5.52
28	1200	5.97	6.27	2.72	2.80
29	1200	4.64	4.80	3.47	3.71
30	850	3.49	3.52	4.81	4.92