# Ultrasonic Hearing: Transient Evoked Otoacoustic Emissions Elicited by Bone-Conducted Ultrasonic Stimuli

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## I Introduction

Transient Evoked Otoacoustic Emissions (TEOAEs) are a form of energy leakage from the cochlea to the ear canal during the active process of stimulus processing by the Outer Hair Cells (OHCs) of the cochlea [1]. TEOAEs can be elicited by short (0.1 - 1 ms) airborne or bone-conducted clicks or tones and can be recorded in more than 98% of normally hearing subjects [2]. Strong TEOAEs indicate normal physiological status of the cochlea.

The intriguing phenomenon of ultrasonic hearing has been investigated since the early 1960's [3]. When presented with bone-conducted ultrasonic stimuli, normally hearing subjects can perceive tones as high in frequency as 100 kHz. Abramovich [4] found an increased ultrasonic threshold of hearing in 81% of the patients having a sensorineural hearing loss associated with hair cell damage. The ultrasonic hearing mechanism has not been fully explained. Skin demodulation, piezoelectric effect of bone and cochlear-level reception have been proposed as underlying mechanisms.

We postulated the existence of TEOAEs due to bone-conducted near-ultrasonic (20 - 100 kHz) stimulation and developed a suitable investigation method and equipment. We recorded ultrasonic bone-elicited TEOAEs and examined their main features.

## II Method

We used the AAS9000, a LabVIEW-based audiometric system currently under development in the Institute, as an investigation tool. The instrument generates tones or clicks and records cochlear responses using a miniature microphone in the Ear Probe (Fig. 1), processes them and displays both the time-domain waveforms and their FFTs for each ear on the computer screen.

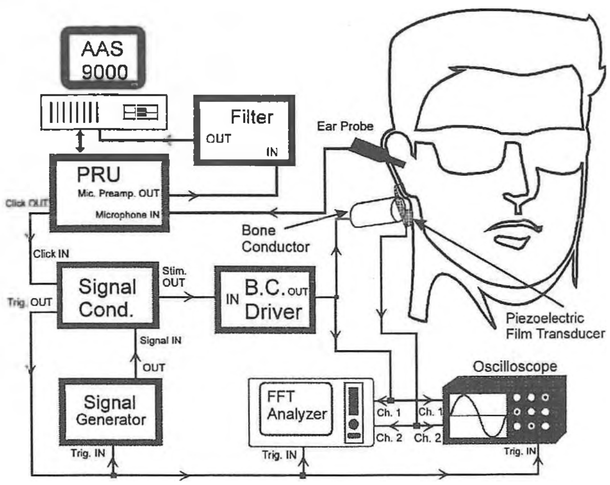


**Fig. 1 Experimental Setup**

During our study, the click normally used for TEOAE stimulation was rerouted to a custom-made Signal Conditioning Board which provides synchronization pulses for the Signal Generator, FFT Analyzer and Oscilloscope. This board also receives ultrasonic signal from the Signal Generator and outputs stimuli of adjustable duration and slope. These signals are further amplified by the Bone Conductor Driver and delivered to the subject's skull using a redesigned Bone Conductor and Headband. A piezoelectric film transducer inserted between the subject's head and bone conductor was used to monitor the shape and frequency spectrum of head vibration. A 40 kHz signal was used as a stimulus.

## III Results

We tested three young male normally hearing subjects.

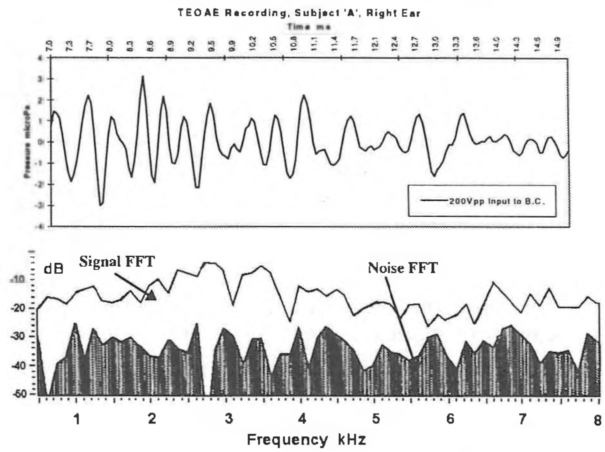


**Fig. 2 Ultrasonic bone-elicited TEOAE**

We found similarities of the ultrasonic bone-elicited TEOAEs to conventionally-elicited TEOAEs with regard to stimulus and response amplitude dependency, duration of the stimulus artifact and of the active response of the ear. The frequency spectrum of ultrasonic bone-elicited TEOAEs (Fig. 2) show stronger high frequency components than conventional TEOAEs, suggesting the method's potential as a fast screening method for the whole audiometric frequency range, from 125 Hz to 8 kHz.

## IV Conclusions

We designed a suitable investigation method, recorded ultrasonic bone-elicited TEOAEs and proved the validity of our hypothesis. Our experimental results suggest that the cochlea is a good candidate for perception of ultrasonic signals because it produces otoacoustic emissions in response to ultrasonic stimuli.

## V References

[1] Kemp, D.T., "Otoacoustic emissions, traveling waves and cochlear mechanisms", Hear. Res., 1986, 22: 95 - 104.

[2] Probst, R., Lonsbury-Martin, B.L., Martin, G.K., "A review of otoacoustic emissions", JASA, 1991, 89: 2027 - 2067.

[3] Corso, J.F. "Bone-conduction thresholds for sonic and ultrasonic frequencies", JASA, 1963, 35: 1738 - 1743.

[4] Abramovich, S.J. "Auditory perception of ultrasound in patients with sensorineural and conductive hearing loss", Journal of Laryngology & Otology, 1978, 92(10): 861-867.