ACOUSTICS 1992

The Executive Council decided in 1987 that several recent and newsworthy advances in acoustics should be selected each year for brief description in a format and in language which would be appropriate for publicizing progress in acoustics through science writers to the general public. Some of these short articles would also be submitted for possible publication in the annual Physics News. *All of the brief articles, to be solicited and selected by the President and Editor-in-Chief, would be published in our* Journal. *The following two articles were selected in 1992.*

Otoacoustic emissions [43.64.Jb]

Ears produce sounds known as otoacoustic emissions (OAEs). Hearing specialists listen to these faint sounds by placing a miniature microphone in the ear canal enabling the inaccessible workings of the inner ear to be monitored. Before OAEs were discovered[1] the only methods available to probe the ear were invasive (therefore damaging) experiments tht could only be performed on animals. Now comparative OAE experiments are possible on both humans and animals, allowing study of the fundamental processes that determine the cochlear sensitivity, tuning, and dynamic range that are uniquely associated with mammalian hearing.

Experimental and theoretical studies reveal that OAEs are produced as a normal-by-product of the hearing process.[2] These emissions are known to result from nonlinear motions of the basilar membrane that act as a source of reemitted bidirectional traveling waves. Determining whether the nonlinear mechanisms responsible for normal hearing are active[3,4] (enhancing the sound-induced motion of the basilar membrane by adding energy to the stimulus-conversion process), or whether they are a passive nonlinear reemission of energy, is still being debated.[5,6]

Recent direct measurements of basilar-membrane motion[7] support the theory that an active, vulnerable, biomechanical process within the organ of Corti uses metabolic energy to enhance the sensitivity and frequency tuning of basilar-membrane vibration. Thus, the more popular theory is that the nonlinear stimulus processing performed by the cochlea reflects the operation of active mechanisms that sharpen and amplify the vibromechanical response to low-level sound. In this view, the organ of Corti is assumed to consist of a series of individual cochlear amplifiers[3,4] distributed uniformly along the basilar membrane. The gain of these amplifiers, assumed to be dependent upon the level of the input signal, provides the nonlinear component in the cochlear-amplifier theory, suggesting that outer hair cells (OHCs) are the physiological counterparts of the cochlear amplifier. In this interpretation, the cochlear amplifier is thought to consist of a feedback loop between basilar-membrane vibration and the motile responses of OHCs to their receptor potentials. In response to acoustic stimuli, the nonlinear component of basilar-membrane motion causes emissions from cochlear-duct locations related to the stimulus frequency, and this response is detected in the ear canal as an OAE.

Otoacoustic emissions can be classified into two general types known as spontaneous or evoked emissions. The tonal, low-level spontaneous OAEs occur naturally in the ears of about 60% of normally hearing individuals[8] in the absence of deliberate sound stimulation. Evoked OAEs, in contrast, are elicited by low to moderate-level test sounds delivered through a probe that is sealed securely in the ear canal. Evoked OAEs, present in virtually all normal ears, can be separated into three subclasses according to the type of acoustic stimulus. Transiently evoked OAEs are elicited by brief clicks. Stimulus-frequency OAEs are elicited by long-duration tones, and occur at the stimulus frequency. Distortion-product OAEs are produced by a stimulus of two primary tones at frequencies f_1 and f_2, and occur at frequencies predictable from precise mathematical relationships. The most prominent distortion-product OAE occurs at the $2f_1-f_2$ frequency. Spontaneous OAEs are not universally present, and stimulus-frequency OAEs are technically difficult to record, so transiently evoked and distortion-product OAEs have been the most intensely investigated. Transient OAEs are mainly studied in humans. Distortion-product OAEs are typically investigated in animal species, rather than in humans, in which they are 25–35 dB smaller. Recently, distortion-product OAEs have become more popular in human measurements, because of the more straightforward interpretation of their generation.[6] Presently, clinical studies are being done to determine the similarities and differences between transient and distortion-product OAEs.

Much current research on OAEs has focused on their use as assessors of cochlear condition in clinical settings. Based on both experimental and applied research,[9] it is widely accepted that the presence of OAEs at average levels indicates normal OHC function. Using OAEs to clinically inspect the functional status of the OHCs has become a powerful interpretive tool giving new meaning to the long-time diagnostic strategy of site-of-lesion testing. Emission tests have provided new insights into common hearing problems caused by aging,[10] Meniere's disease,[11] idiopathic sudden sensorineural hearing loss,[12] and acoustic neurinoma.[13] In addition to documenting the various types of emissions in diseased ears, other efforts have been aimed at establishing statistical databases describing normal responses[14] to permit the more objective identification of pathologic ears.

Investigators have also used evoked OAEs to identify cochlear impairment in difficult-to-test patients such as newborn and young infants,[15] and young children.[16] The most commonly proposed application in the neonatal population is to screen hearing. Initial results from ongoing clinical trials[17] suggest that it is feasible to use transiently evoked OAEs as a detector of hearing impairment in every newborn child.

It is 15 years since the different types of OAEs were first described. However, only relatively recently have emissions become intensely studied phenomena. In 1980, a few years after their discovery, 20 reports on OAE phenomena were published. In contrast, during the first six months of 1992, more than 60 publications have appeared. Nourished by the great insight that emissions have contributed to our knowledge of how the normal ear operates, and by the distinct benefits they provide in diagnosing and understanding ear problems, it is clear that OAEs have become a crucial method for exploring cochlear function.

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Imaging plumes beneath the sea [43.30.Pc]

The spectacular plumes that issue from deep-ocean hot springs have been imaged for the first time using underwater sound.[1] The images were obtained during a test of a prototype imaging sonar system developed by the National Oceanic and Atmospheric Administration and the Naval Research Laboratory. The development effort was based on an earlier feasibility study.[2]

The plumes form when hot, metal-rich solutions discharge from chimney-like vents on the seafloor. They contain clouds of micron-size metallic mineral particles that buoyantly rise in the flow. The metallic mineral particles suspended in the plumes backscatter sound from the sonar system to form images. When viewed from a submersible vehicle, the venting chimneys look like factory smokestacks belching black smoke. Hot springs having such black smoker chimneys are distributed worldwide along the submerged volcanic mountain ranges that exist beneath the oceans. They transfer great quantities of chemicals and heat from the Earth's interior to the ocean and, in the case of gases like carbon dioxide, to the atmosphere. Imaging the plumes is vital to understanding the impact of this transfer on the global environment.

The sonar was mounted on the U.S. Navy Deep Submergence Vehicle *Turtle* for the test. Diving to a depth of 2600 m off the southern tip of Baja California at a site where deep sea hot springs were first discovered in 1979, plume images were recorded from two adjacent black smoker chimneys. With the submersible vehicle sitting stationary on the solidified lava flows that cover the seafloor at the site, the sonar was programmed to scan the plumes up to a height of 50 m above the chimneys. The scans, representing individual slices through the plumes, were displayed in real time in the vehicle and were also recorded for subsequent processing using advanced computer graphic techniques (see Fig. 1).

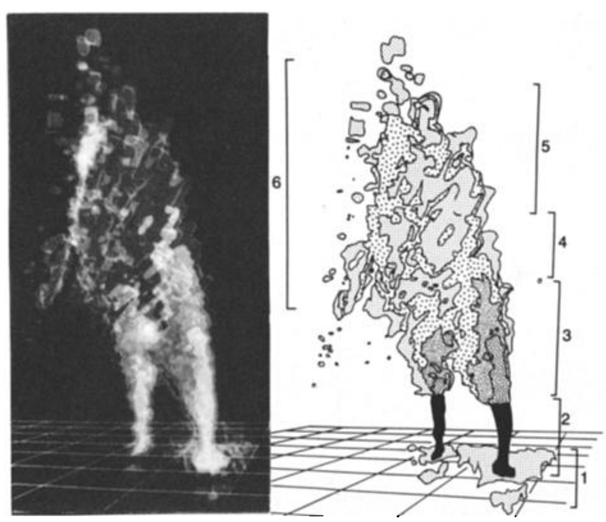

FIG. 1. Sonar image of black smoker plumes discharging from two adjacent chimneys and buoyantly rising 50 m recorded at a depth of 2600 m in the Pacific off Baja California (left) and a line drawing of the image (right).[1] The different patterns and numbers on the line drawing depict zones of progressive dilution of the plumes by mixing with surrounding seawater as they rise. The plumes were bent to the left (north) by the prevailing current.