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Scattering of Sound by Isotropic Turbulence

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commonly experienced during the latter part of a series of 110-db bursts. Subjects differed significantly in their rate of accumulating additional loss in acuity. We conclude that number and rate of burst-pip sequences are important variables to be controlled in studies of "auditory fatigue" and/or "adaptation." The reaction of an ear to repeated stimuli appears to have possibilities as an index of the ear's susceptibility to stimulation deafness.

* Sponsored by U. S. Air Force School of Aviation Medicine.

L9. Channels of Reception in Pitch Discrimination. ANDREW G. PIKLER* AND J. DONALD HARRIS, *Naval Medical Research Laboratory, New London, Connecticut.*—Pitch discrimination was studied in four normal-hearing subjects monaurally, binaurally, and in a variety of other channels of reception. There was no difference in sensitivity between the two ears of any subject, nor were there differences in sensitivity of the monaural channels and the binaural channel, provided all channels were carefully matched in loudness. All channels were equivalent under conditions of matched loudness, except the successive interaural channels (standard stimulus in right ear, variable stimulus in left, and vice versa). These channels showed some slight deterioration of sensitivity and some increase in variance which can be attributed to momentary fluctuations of diplacusis. Similar fluctuations were also found in a channel utilizing a monaural standard stimulus and a binaural variable stimulus, the stimuli in the two ears being matched for loudness. Under these conditions, furthermore, a third pitch is sensed, a phenomenon we term triplacusis. Triplacusis must arise from interaural interactions, and indeed the data as a whole point toward a heavily nonperipheral explanation of pitch discrimination.

* Now at Navy Electronics Laboratory, San Diego, California.

L10. (Abstract withdrawn.)

L11. A Recorded Test for Determining Absolute and Masked Thresholds of Clicks, Bands of Noise, and Warble Tones. J. C. WEBSTER AND J. F. NICKERSON,* *Human Factors Division, U. S. Navy Electronics Laboratory, San Diego 52, California.*—A test has been constructed to screen out men who cannot hear well in low levels of noise and/or who have absolute hearing losses of 25 db or more. The test signals consist of one-millisecond clicks, or $\frac{3}{4}$-second pulses of various sounds. For low-frequency acuity pulses of 200–800 cps noise and tones warbling at a 5-cps rate for an extent of 62.5 cps around 500 cps are used. For high frequency acuity a 5000-cps click, pulses of 1600–6400-cps noise, and pulses of a warble tone of 4000 ± 125 cps are used. A warble-tone-pulse of 1000 ± 125 cps, and a 1000-cps click are used for testing the middle or working frequency acuity. These signals are always heard in a background of noise shaped to provide approximately equal masking at all frequencies. The levels of noise vary so as to cause zero, 25, or 35 db of masking at various times throughout the test. If the test is given our earphones the ambient room noise (over-all level, flat position) can reach 50 db without invalidating the test results. The mechanics of the test construction and some preliminary results of using the test will be presented.

* On a sabbatical leave from the University of Kansas, Lawrence, Kansas.

FRIDAY MORNING, JUNE 25, 9:00 A.M.

The Rudolph Koenig Session on Instrumentation

F. V. HUNT, *Chairman*

Contributed Papers

M1. Noise Characteristics of Cathode-Follower Input Stages. FRANCIS X. BYRNES, *U. S. Navy Electronics Laboratory, San Diego 52, California.*—Cathode followers are frequently used as the input stage for transducers with capacitive impedances; condenser microphones, crystal or ceramic microphones, and hydrophones are examples. The primary purpose of the cathode-follower-type connection rather than the plate-loaded connection for the input stage is to present a higher load impedance to the transducer, thus extending its low-frequency response. An additional advantage which is sometimes claimed for this circuit is that the signal-to-noise ratio is improved. This is supposed to be due to the greatly increased effective value of the input resistor, which in turn means a smaller resistive component and therefore smaller thermal noise of the input impedance. It will be shown both analytically and experimentally that this signal-to-noise ratio does not improve with the cathode-loaded connection and, in fact, in most cases is poorer than with the plate-loaded connection. A comparison of the signal-to-noise ratio for each of these connections with other factors held fixed will be shown. Other circuits which combine both the better noise characteristics of the plate-loaded circuit and the high input impedance of the cathode follower will be shown.

M2. New Developments in Stereophonic Sound. B. PAULSON, *Ampex Corporation, New York, New York.*—Stereophonic sound represents the latest and most promising effort in audio technology towards achieving realistic reproduction of recorded sound. A summary of the developments in stereophonic recording from its inception will be presented. Present-day status of the art will be analyzed, emphasizing new fields for the use of stereophonic recording techniques. The technical details of the Ampex 3-channel stereophonic recorder will be described, and this equipment will then be utilized in a demonstration of various stereophonic recording techniques.

M3. Scattering of Sound by Isotropic Turbulence. ISABURO HORIUCHI, *Acoustics Laboratory, Columbia University, New York, New York.*—Existing information concerning the characteristics of atmospheric turbulence is analyzed, and some representative figures on the resulting scattering of sound to be expected are obtained. The nature of such turbulence, the extent and causes of the anisotropy near the ground, the variation in its character with altitude, and the extent to which approximation of isotropy are valid are discussed. Other micrometeorological parameters are considered and their effects on sound propagation in comparison to those caused by velocity fluctuation estimated. A reasonable spectral function for isotropic turbulence is applied to a scattering cross-section expression derived by Kraichnan to obtain numerical results for the scattering. These are compared with recent experimental data.

M4. The Application of Correlation Techniques to Some Acoustic Measurements.* K. W. GOFF, *Acoustics Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts.*—This paper discusses the application of an analog correlator, computing the crosscorrelation function between two sound pressures, to such measurement problems as the localization of noise sources, the determination of transmission loss, and the measurement of room transient response. The crosscorrelation function $\phi_{21}(\tau)$ between two nonperiodic signals will have a peak in amplitude if a component of each signal originates from a common source. The value of time delay τ for which this peak occurs equals the difference in time required for the individual components to propagate from the common source to the two points under study. An analog electronic correlator has been constructed which, by employing the above-mentioned property, can separate the acoustic signal at a given point into components according to: (1) their points of origin (assuming independent sources), and (2) the transit time from source to the point in question. Preliminary experimental results substantiate methods for determining the amount of sound contributed to a given point by each of several sources and for measuring transmission loss using the correlator to separate the signal transmitted directly through the structure from the flanking signal on the basis of arrival time.

* Sponsored by the U. S. Office of Naval Research.

M5. An Automatic Data Reduction System.* BILL G. WATTERS, JORDAN J. BARUCH, AND GEORGE W. KAMPERMAN, *Bolt Beranek and Newman Inc., Cambridge, Massachusetts.* —The problems involved in manually reducing acoustical data obtained on extensive field noise surveys make this phase of the job an exceedingly tedious one. Instrumentation has been developed to perform the reduction techniques automatically from tape-recorded field data. Once the correction numbers for the recording system have been inserted, the system will plot a narrow band analysis, a ⅓ octave band analysis, or an octave band analysis of a sample of the noise. The ordinate may be either peak pressure level, rms pressure level, or average pressure level. Facilities have been provided for taking samples from several points (such as the equal area points on a grid) and averaging the squares of the pressures, thus yielding an average intensity over the grid. For the case where the areas are not equal, weighting functions may be introduced.

* This work was supported by the U. S. Air Force under Contract AF 33(616)-2151.

M6. Time Distortion in Magnetic Recording.* F. MANSFIELD YOUNG, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*—Time distortion introduced by the magnetic recording process is studied theoretically and experimentally. Problems of discriminating between actual time fluctuations and effects of noise are treated. Both recorder and tape are responsible for observed fluctuations. Measurements of the components due to tape alone are in excellent agreement with theoretical results obtained from a statistical model of the tape.

* This project is supported by BuShips.

M7. An Electronic Distribution Analyzer.* F. MANSFIELD YOUNG, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*—A direct indicating instrument for the measurement of the unconditional probability density function of an input signal has been developed. Either statistically stationary or repetitive inputs can be analyzed. Integration times up to 1000 seconds are available. Examples of measured distribution functions of speech and music will be shown.

* This project is supported by BuShips.

M8. Hydrodynamic Feedback Oscillators. JOHN V. BOUYOUCOS, *Acoustics Research Laboratory, Harvard University, Cambridge, Massachusetts.*—The conversion of fluid-flow energy to acoustic energy by means of a controlled, variable-area orifice is described. Such an orifice acts as a variable flow-impedance device, and it is shown that for small variations of area a simple circuit representation may be obtained which involves an acoustic pressure or volume velocity "source" of finite internal impedance. Although such a mechanism is actually a "displacement-controlled" device, the area-variation can be "sound pressure-actuated." Thus the network representation of the system can have the form of a four-terminal, unilateral, acoustic transducer which is, in many respects, similar to the vacuum tube. Acoustic feedback may be employed between these terminal pairs to originate and sustain the energy conversion process, thus giving rise to self-excited oscillations. Most of this converted energy is available to be dissipated in an acoustic load, since only a small fraction must be returned to the system to maintain the excitation. A number of oscillator configurations are illustrated, some of which are analogous to common vacuum-tube systems. (This research has been aided by funds made available under a contract with the U. S. Office of Naval Research.)

M9. A Two-Projector Method of Absolute Calibration at Low Audio and Infrasonic Frequencies. W. J. TROTT, *U. S. Navy Underwater Sound Reference Laboratory, Orlando, Florida.*—An absolute method is described for calibration of hydrophones which, unlike other absolute methods, depends on a frequency-independent factor that is easily measured statically. One projector is equipped with a displacement measuring circuit. The factor 0.1 *Bl/Area* plus voltage and current measurements yield the hydrophone receiving response.

M10. An Improved Ear Defender Cushion. E. A. G. SHAW AND G. J. THIESSEN, *National Research Council, Division of Physics, Ottawa, Canada.*—In designing ear defenders of the cover type for protection against sound the cushion presents a serious problem. To provide an airtight seal against an irregular object like the side of the head, the cushion is usually made quite soft. This, however, contradicts the requirement of a cushion with a high spring constant which is necessary to prevent the cup from vibrating at low frequencies. This contradiction is resolved by the use of an annular sheath which is filled with a liquid or semisolid. The high bulk modulus of the liquid prevents appreciable volume changes of the cushion due to the sound pressure while the high Young's modulus of the sheath prevents area change. The vibration of the cup is greatly reduced while the thin sheath offers no great rigidity to impede fitting the head. Low frequency attenuations as high as 34 db have been obtained when a solid material is substituted for the head. This is much higher than the limit set by the compliance of the skin and flesh on the head.