Harvey Fletcher

by William J. Strong and Jont B. Allen

Harvey Fletcher (1884-1981) was a founding member and first president of the Acoustical Society of America. He made important research contributions to electron physics, speech and hearing, communication acoustics, and musical acoustics. Among these were contributions in the development of the audiometer, electronic hearing aids, stereophonic sound, the artificial larynx, and sound in motion pictures. He, with his colleagues, introduced or quantified the concepts of articulation, loudness, and critical band. Along with his many colleagues, Fletcher made many experimental measurements to define and support these new concepts. He has been described as “a singular intellectual force in the development of present- day communication acoustics and telephony.”

Harvey Fletcher was born in Provo, Utah on September 11, 1884 and grew up in a family of five boys and three girls. The family enjoyed camping trips and father and sons enjoyed fishing. After a day of fishing success Harvey was challenged by a coyote on the trail back to camp. He stunned the coyote with a rock and ended the day with a large string of fish and a coyote.

He almost decided to forego school after the eighth grade but enrolled in the Brigham Young Academy because he thought it would be fun to be with his schoolmates again. He neglected the assigned work and failed his first high school physics class, then repeated the class, received A+, and became a lab assistant. He completed a three year B.S. degree at the BYA in 1907. During this time he and friends put their book learning to work by contracting trench digging for the Provo water supply, laying out the block “Y” on the east mountain, and surveying large sections of land for the government.

Harvey took his new bride to Chicago in the fall of 1908 to begin study for his Ph.D. where Dr. Robert Millikan had been using water droplets in an attempt to measure the charge on the electron. In the fall of 1909 Dr. Millikan told Fletcher that his thesis was to try a substance other than water in the study of the electron charge. He immediately went to a drugstore and bought an atomizer and watch oil. He assembled an apparatus that gave him fairly good results the first day. It took several days to draw Millikan’s attention to his new results, but once Millikan saw what young Harvey had done, he worked with Fletcher every day over the next two years. Although Fletcher carried out much of the work on the oil-drop experiment and even wrote the papers, publication of the results listed only Millikan as author and was largely responsible for his Nobel Prize. Fletcher received his Ph.D. in physics “summa cum laude” in 1911.

After graduation he was offered a position in research at the Western Electric Company. However, he felt an obligation to return to BYU where he served as head of the Dept. of Physics and taught and carried out research for the next five years. During this time he mentored Carl F. Eyring, Wayne B. Hales, and Vern O. Knudsen. Finally, he responded to Dr. Jewitt's yearly importuning in 1916 and accepted a position at Western Electric. His first years there were spent installing telephones, repairing telephone equipment, and working on wartime acoustic technology.

Immediately following WWI Fletcher was able to get his research in communication acoustics underway. The newly created vacuum tube electronic technology enabled a renaissance in acoustics research. More precise measurements were made of the threshold of audibility. Since the commodity being delivered by the telephone business was reproduced speech, it was necessary to measure the effectiveness of different telephone systems. Fletcher's articulation theory quantified the transmission properties of a transmission system without the need for time consuming speech recognition testing. Articulation was defined as the probability of correctly transmitting nonsense speech sounds through a telephone channel. Fletcher showed that high and low frequency articulation bands could be made additive after a nonlinear transformation. Fletcher and colleagues defined an articulation index for which temporal fluctuations in the speech signal, in contiguous frequency bands, contributed independently to articulation, and the separate contributions were additive. Calculation of the articulation index took level, frequency distortion, and noise into account for each band

Loudness of speech as a perceptual quantity was important in telephony so Fletcher and colleagues made an effort to determine the dependence of loudness on physical quantities. In a classic 1933 paper Fletcher and Munson defined loudness, presented equal-loudness level contours (expressed in phons), and provided loudness units (proportional to sones) having direct correspondence to perception. They expressed loudness of single tones in terms of the one-third power of intensity. They demonstrated that loudness is additive for frequency components in separate critical bands or in separate ears. They further demonstrated that loudness is additive when masking is present, if the masked loudness contributions are properly weighted. They devised an innovative technique for the measurement of loudness, based on his observation of the additivity of loudness.

The critical band concept had its genesis in the 1933 paper. Fletcher could see that loudness added for "non-interacting" frequencies. For "interacting" frequencies masking intervened and weighted loudnesses added because these interacting frequencies were competing for many of the same hair cells. They showed that partial loudness and masking are closely related. Details of the critical band were worked out from 1934-38 to provide loudness summation schemes for speech and noise where masking is always an issue.

Fletcher published five papers in the area of atomic physics, two of which were coauthored with Robert A. Millikan. He published numerous papers, several of which were coauthored with Munson, Steinberg, and Wegel, in the broad area of human hearing and communication. In addition to his research publications and patents, Fletcher attempted to integrate then current knowledge in his 1929 *Speech and Hearing* and in his 1953 *Speech and Hearing in Communication* .

Fletcher had a lifetime interest in people with speaking and hearing problems. (His own father suddenly lost his hearing at age 55.) He and co-workers used the electronic technology of the time to develop instruments useful to this community. Various versions of the audiometer were developed and made available to clinicians and schools. A vacuum tube hearing aid was developed for Alfred Dupont, later versions of which were made available to Thomas Edison. (Fletcher had many interesting stories to tell about hearing aids and the people to whom they were introduced.) An artificial larynx was developed for a Mr. Mapes. Western Electric manufactured audiometers, hearing aids, and artificial larynges after these developments. A group hearing system with 100 headsets was developed for meetings of hard of hearing persons at the League for the Hard of Hearing in NYC.

A meeting was held December 27, 1928 at the Bell Labs to consider organization of an acoustical society. Much discussion ensued among the forty persons present and the decision was made to organize the Acoustical Society of America. A committee was appointed to prepare a constitution. At the first official meeting of the ASA held May 10-11, 1929, Fletcher was elected first president of the Society. He was the ASA representative to the organization of the American Institute of Physics in 1932, an Institute to which the ASA belongs as a member Society.

After Fletcher met Stokowski they jointly made tests of stereophonic sound. They settled on a three channel system: left, right, and center. They demonstrated this system on April 27, 1933 with the Philadelphia Orchestra on stage at the Academy of Music in Philadelphia and the reproduction in Washington, D.C. Mr. Stokowski was at the controls in Washington. There were many dignitaries in attendance and the demonstration was considered a tremendous success. Many acoustic tricks were used to impress the crowd. At one point a tap dancing tenor split into two people, with the physical body going in one direction and his sound going in another, which caused the audience to gasp in disbelief.

During his time at Bell Labs Fletcher was appointed Director of Acoustical Research in 1928 and Director of Physical Research in 1933. During WWII he had charge of groups in acoustics at six universities along with several at Bell Labs. He retired from Bell Labs in 1949. He started an acoustics program at Columbia University while in the Electrical Engineering Dept. during 1950-1951. He returned to BYU in 1952 as director of research. He later helped organize the engineering program and served as Dean of the College of Physical and Engineering Sciences from 1954 to 1958. He taught mathematics and acoustics for two years and then turned his attention to research in musical acoustics.

Fletcher had a longtime interest in musical acoustics as evidenced by early (1924) publications on perceptual aspects of musical tones. However, his active involvement in musical acoustics research came only after his multiple retirements. He and co-workers set about to determine the physical attributes of musical instrument tones that are most strongly correlated with their perceptual attributes. The general approach in these studies was to record instrumental tones, analyze these tones to determine their spectral content, and then synthesize the tones with the 100 oscillator tone synthesizer (see figure). Recorded natural and synthetic tones were presented to listeners who were asked to judge the tones as being real or synthetic. When listeners were unable to distinguish between the two, the synthetic tones were considered to contain the essential components of the real tones. They published four papers on piano, organ, and bowed string tones. He published a paper on frequencies of stiff piano strings. His final paper in 1978 was on bass drum, with Irvin Bassett.

Fletcher received numerous honors for his scientific contributions, including honorary doctorates from six institutions of higher learning and gold medals from four professional societies. He served as president of the Utah Academy of Science, the American Hearing Society, and the American Physical Society. He served as a member of the Noise Abatement Commission of New York City. He served the Church of Jesus Christ of Latter-day Saints as president (pastor/priest) of its New York Branch (congregation) for ten years and as president (bishop) of its New York Stake (diocese) for six years. He coauthored a book, *Science and Your Faith in God*, and influenced the spiritual lives of thousands of young people.

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