

Recent Trend of Acoustical Science

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The progression of acoustic science has a very long history, dating back to the age of the Greek philosopher Pythagoras. As everybody knows, sound is generated by vibrations travelling through a medium, such as air, and is then captured by our ears as physical stimulus. However, the mechanism of sound transmission remained unexplained for generations. It took many years for scientists to discover the mechanisms that form our auditory system. The recent development and diffusion of electronic technologies have brought about rapid advances in acoustic devices. Furthermore, the evolution of microphones, speakers and other electric devices and circuits has led to significant progress in acoustic research. The rapid advance of electronics helps to shed a new light on the field of acoustics research, one of the traditional fields of physical science.

First, let us examine the history of acoustic science and related trends in recent years.

1) Changes in Sound and Voice Recording Media

In May 1976, the Institute of Noise Control Engineering of Japan was founded by people working in the field of noise and vibration control. Comprised of professionals from industry, civil engineering, consulting services, central and local governments, universities and research organizations, the main intent of the institute was to promote the study of noise and vibration control, and to strengthen the close exchange of communication and information among related parties. These activities have continued for almost 30 years. With the rapid industrial growth in this age, environmental protection has become a major public concern, and noise control is an integral part of this social interest. Acoustic science has played a significant role in this area. Scientific technology has made considerable progress over the course of the last 50 years. In particular, electronic and digital technologies continue to evolve at an incredible rate. Microphones, speakers and amplifiers are electronic devices common to our daily life. Most of these devices, though small in size, deliver high performance, stability, durability and are low-priced. I used to struggle with a microphone that was noisy, had poor sensitivity, and contained heavy batteries and power-consuming vacuum tubes. Though that was not so long ago, I feel as if more than a century has passed since then.

I went to a movie theater for the first time in over 10 years. I was impressed by the huge screen, as I usually watch DVD movies on my TV at home. Moreover, I was simply amazed by the deafening sound effects. The first movie with sound was released in America **in 1927**, or at the beginning of the Showa era. In Japan, the first sound film (entitled “The Neighbor’s wife and Mine”) was created **in 1931** by Shochiku Kinema. Until then, silent movies with live narration were popular in Japan.

In the old days, recording sound was not easy or widespread, and there many problems involved.

At this time, “recording” referred to the act of creating an audio record. The first recording was attempted more than 100 years ago when Thomas Edison used a wax drum (Fig. 1) to invent a sound storage device (phonograph). With this device, sound waveforms were inscribed onto a rotating wax drum.

Table 1 lists major recording media that have been developed, up until the present.

Table 1: History of Recording Media

| Year | |
|------|---|
| 1877 | Edison invented the phonograph. |
| 1890 | Telephone services started in Tokyo and Yokohama. |
| 1891 | Japan’s first wax drum record |
| 1909 | Japan’s first disc record (SP record) |
| 1925 | AM radio broadcasting started in Japan. |
| 1950 | Tape recorder |
| 1951 | LP record |
| 1951 | Commercial AM radio broadcasting started |
| 1963 | Compact cassette tape |
| 1963 | NHK started FM stereo broadcasting |
| 1976 | Home VTR (VHS system) |
| 1979 | Mobile phone available for practical use |
| 1979 | Walkman |
| 1981 | LD (laser disc) |
| 1982 | CD (compact disc) |
| 1987 | DAT (digital audio tape) |
| 1992 | MD (mini disc) |
| 1996 | DVD |
| 2001 | iPod (digital recording medium) |

In addition to the recording technologies listed in Table 1, let now me talk about onomatopoeical sound tools.

Onomatopoeia is a collection of words that express sounds or voices, such as “bow-wow,” “mew-mew,” “tweet-tweet” and “tap tap.” Fig. 2 shows a bird call, an onomatopoeic tool that mimics the song of a nightingale.

Fig. 3 indicates another sound tool, which is called the “rain stick.” It is made of a hollow cactus branch with the thorns inserted from the inside. This tool mimics the sound of rain when hard dry seeds poured into the hollow space and brush against the thorns. Because we can use them to reproduce the intended sound at anytime, these sound imitators may be considered to be a kind of sound storage device. Other examples include a dove/pigeon whistle, a bush warbler flute, and a cicada toy (See Fig. 4). Many onomatopoeic tools have been used by man since ancient times².

It will be interesting to note the traditional sound tools mentioned above when we review the history of audio recording media.

Now let us return to the phonograph.

In 1887, or 10 years **Thomas Edison** invented the phonograph, **Emile Berliner** further improved this technique by modifying the **cylindrical** element and adopting a flat disc (later called a “gramophone record”). In 1888, Oberlin Smith, a mechanical engineer, (1840 - 1926) proposed the idea of electromagnetic recording as an alternative to mechanical sound wave recording. Based on this idea, **Valdemar Poulsen (1869 - 1942)** completed the first magnetic recorder, using a magnetized steel piano wire as the recording medium. This device provided the original concept for the wire recorder. However, the original wire recorder prototype was massive, and its performance was not stable enough to allow for practical use. Vacuum tubes did not exist at this time, and it wasn't until **1904** that the diode was developed by **John Ambrose Fleming**, the physicist known for electromagnetism.

Two types of recording techniques were used: (1) Disc recording that mechanically inscribed sound waveforms onto discs, and (2) Movie film (sound track) recording that employed an optical method (1920's).

Talkies used an optical method that converted sound waves into light and photographically recorded them on film. This technique was often used in acoustic research. Fig. 5 illustrates the simplified mechanism of this technique. This picture has been extracted from a technical guide to talkies¹. (Source: Kobayashi Institute's library)

Still, optical talkies and wire recorders were heavy and large. They had to be fixed on a solid and stable surface, and thus were used only by broadcasting stations and telephone companies.

With the onset of World War II, the use of acoustic signals for military purposes attracted widespread attention. In the United States, around 1940 Bell Laboratories and other research organizations started to develop small-sized magnetic

recorders that could be used by forces on land, sea, and in the air forces. This technique was crucial for deciphering the correspondence of the enemy. Small and reliable recorders were needed that could be used on moving warships and in the harsh conditions of the battlefield. To fulfill this need, a mobile machine was developed, as shown in Fig. 6.

Before the introduction of the tape recorder, the gramophone disc record was the only medium available in Japan. This kind of disc record was used to broadcast the Japanese emperor's surrender address.

After the war, wire recorders that had been employed for military purposes were placed on the market for civil use. However, they were not popular among the public because of the poor sound quality, handling problems, and high price.

Around 1950, Tokyo Telecommunications Engineering Corporation (predecessor to Sony) developed a recorder/player system that used magnetic tapes. The initial model used a strip of paper coated with iron oxide powder. These paper tapes were later replaced by plastic tapes.

During the 1960s, reel-to-reel tape recorders were widely used by the public and research organizations.

Nicknamed “Densuke” in Japanese, these early reel-to-reel tape recorders were used for street-corner interview programs, and gained a great deal of recognition during the post-war period. In spite of their heavy weight, short recording time and low sound quality, magnetic tape recorders were an essential part of acoustic research, and various recorders were developed for specific applications. Fig. 7 shows a product composed of a mechanical drive and an amplifier that contains vacuum tubes. I once used this kind of machine. Though I was satisfied with its performance, I had a lot of trouble lugging it around but because it was extremely heavy and large.

Fig. 8 shows the tape recorder that was commonly used at school and home.

Enclosed in a wooden box, this machine contained a number of hot vacuum tubes, resistors, condensers, and transformers. After the power switch was turned on, it took several minutes until the vacuum tubes were warm enough for stable operation. The popularization of transistors led to the development of smaller electrical circuits, and thus smaller and more light-weight tape recorders that consumed less power. Soon after, miniature tape recorders with excellent acoustic characteristics became available, making on-site recording much easier. Fig. 9 shows a compact open reel recorder. You may remember seeing this machine used in the TV series “Mission Impossible.” A recorded voice explained the basic instructions for the mission, ending with the famous line:

“Good luck, Jim. This tape will self-destruct in five seconds.”

The tape would then disintegrate in a cloud of smoke. With the advent of the cassette tape recorder in 1960s, open-reel recorders gradually fell out of use. Vacuum tubes were replaced by transistors, and diodes for electric circuits. Smaller motors were employed for mechanical units. The magnetic head was also miniaturized, enabling a dramatic downsizing of the entire machine (Please refer to Fig. 10 for the initial cassette tape recorder).

As an easy-to-use music player, the cassette tape recorder became a standard fixture in the car stereo and gained great popularity. In 1977, the “Walkman” was released on the market and quickly embraced as a personal stereo. Young people wearing earphones became a common sight. Next, micro cassette and digital recording technologies were developed. With the emergence of the large-capacity hard disk, technological innovation proceeded at an amazing speed. Combined with precision processing, digital technology gave rise to the development of the MD (micro disk). Conventional magnetic tape recorders have now been almost entirely replaced by this new media.

Since the advent of CD in 1990s, digital flash memory has been increasingly used for sound recording. A variety of products are now available at extremely low prices. Since the invention of the first recorder by Edison, various attempts have been made to enable sound to be recorded and reproduced as desired.

The electronic and digital technologies have successfully solved this problem and continue to make advancements. New products are continually introduced on the market one after another. In large electronic stores, magnetic tapes have been shoved into a small corner of electric appliances.

Open-reel magnetic tapes once so popular among music fans have almost all but disappeared. It’s a pity to see these changes.

Sound is a physical phenomenon that can only exist with the passage of time. Recording this live event has been made possible through considerable amount of effort and inventive ideas. Beginning with the first attempt to imprint sound waveforms into grooves on discs, recording technologies have evolved to the current level of quality we enjoy today.

Fig. 1 Wax drum phonograph (Museum for the Science of Sound, Kobayashi Institute of Physical Research)

Fig. 2 Bird call

Fig. 3 Rain stick (Museum for the Science of Sound, Kobayashi Institute of Physical Research)

Fig. 4 Bush warbler flute and a cicada toy

Fig. 5 Picture from a technical guide to talkies

Fig. 6 Wire recorder (Museum for the Science of Sound, Kobayashi Institute of Physical Research)

Fig. 7 Tape recorder (KP2) (Museum for the Science of Sound, Kobayashi Institute of Physical Research)

Fig. 8 Tape recorder commonly used by the public (Museum for the Science of Sound, Kobayashi Institute of Physical Research)

Fig. 9 Ultra compact, open reel tape recorder (Museum for the Science of Sound, Kobayashi Institute of Physical Research)

Fig. 10 Initial cassette tape recorder (Museum for the Science of Sound, Kobayashi Institute of Physical Research)



Fig. 1



Fig. 2



Fig. 3

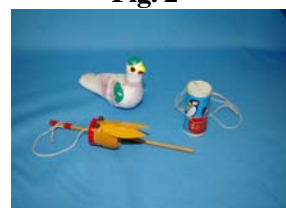


Fig. 4

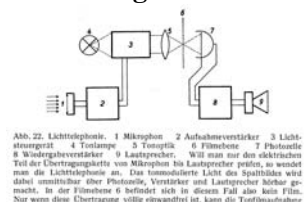


Fig. 5



Fig. 6



Fig. 7



Fig. 8



Fig. 9



Fig. 10

2) This Year’s Acoustic Science Trends

With the recent increase in the elderly population, the proportion of aged people is rapidly growing.

Within this aging society, we now encounter a variety of new social issues that have not yet been experienced. One major issue is hearing impairment among the elderly. This has resulted in a rise in car accidents caused by senior drivers. People with hearing problems are at greater risk of being involved in traffic accidents because they cannot catch the sounds heard by people with normal hearing ability. Hearing loss is caused by various different factors, such as heredity, infection from disease, drugs, and loud noise. However, a decrease in auditory sensitivity caused aging is going to become a serious social problem in the near future.

In light of this, hearing impairment has emerged as one of the major fields of acoustic research.

Following is a description of the current situation and future trends of hearing aids.

1. History of hearing aid development

Until recently, the principles of auditory sense remained largely unexplained. The history of hearing aids in Japan stretches back to the Edo period (1603 - 1867). At a museum, we can see an advertising handout depicting a hearing aid labeled "earglasses" (due to association with "eyeglasses"). This primitive hearing aid was a trumpet style sound collector invented by Shiba Kokan (1747 - 1818). Ancient hearing aids also used seashells and cattle-horns. These sound collectors evolved into artificial ear trumpets and sound receivers for aircrafts (when airplanes flew at low speeds at low altitudes). One unique hearing aid may be a sound collector that was embedded into a large chair.

In central Bonn, Germany, the birthplace of Beethoven is preserved as a museum. Visitors to this great composer's home can see an array of ear trumpets in all shapes and sizes, among a number of other exhibits, such as hand-written scores, quill pens, classic keyboard instruments and other articles related to the composing work of Beethoven. As is widely known, Beethoven suffered from hearing loss during the later years of his life. One of his friends, a metal worker, manufactured trumpet style hearing aids as ordered by the great composer. It may be inappropriate to call these trumpets "hearing aids", because they simply amplify the sound that is transmitted to the ears. Throughout the history of hearing aids, a number of similar instruments have been introduced (please refer to the attached figure). These trumpet style hearing devices adopt the empirical concept of amplifying (or collecting) sound, in much the same way that you cup your hands around your ears when you strain to catch a faint sound.

With the advent of electronics in the 1920s, new hearing aids that employed electrical circuits were developed. Using vacuum tubes and large-sized batteries, these devices suffered from considerable noise and unreliable performance. Vacuum tube hearing aids were improved and their basic functions were further enhanced. (Vacuum tube hearing aids during the 1950s)

Following the invention of transistors and integrated circuits, ultra small behind-the-ear and in-the-ear hearing aids were developed and made available to the public. And then finally came the age of digital hearing aids that incorporated microcomputers. This topic will be detailed in a separate section.

2. The role and importance of hearing aid fitting

Concerning the role of hearing aids, it should be especially noted that amplifying sound is not all that is required of these devices. The conditions that lead to hearing loss differs for each individual, so each hearing aid must be custom-made to fit that particular user's needs, in much the same way clothes are tailor-made. A detailed auditory examination must first be conducted, and the resulting data should be utilized to develop a hearing aid that possesses characteristics needed to compensate for the lost ability. This is important process, known as "fitting", is needed for applying the appropriate hearing aid. Just as optometric check is required for anyone buying eyeglasses, fitting is essential for selecting the suitable hearing aid.

In the past, hearing disorders were sometimes further aggravated by large trumpets that poured loud sound into ears. You should remember that giving an elderly person, who is hard of hearing, a hearing aid that you selected yourself is not a good deed at all.

3. Features for improved speech intelligibility

(1) Size of hearing aids: Is small really good?

As hearing aids are being made smaller and in-the-ear models are improved, the microphone, earphone and battery are all integrated within an extremely small space. Naturally, the user-operated power switch and volume control dial are also miniaturized. Small and lightweight are desirable for instruments that are to be inserted in the ear. However, having to manipulate tiny switches and buttons may not always be pleasant for the user. For elderly people in particular, it can be burdensome to operate these extremely small parts. Although highly functional mobile phones

became widespread at an amazing speed, simpler models are increasingly popular among older people. These mobile phones are not as small as standard models, and feature easy-to-use switches and larger letters on the display. For elderly people, hearing aids need to be made in sizes that help to facilitate their operation. Larger size would also make it easier to compensate for functional limitations that are often encountered with miniature products. For example, a large-sized battery allows longer, continuous use and enables additional functions for improved sound quality, such as the choice of frequency bands. While predominant trend for hearing aids is shifting towards extremely small and lightweight designs, larger size hearing aids might be more desirable for certain portions of the population.

- (2) Directional microphone
- (3) Noise reduction
- (4) Impulsive noise reduction
- (5) Suppression of acoustic feedback and howling

4. Additional features to enhance usability

As an essential tool within the daily life of people with hearing problems, hearing aids need to have various features that offer improved convenience for the user.

- (1) Size reduction or miniaturization
- (2) Waterproof
- (3) Battery depolarization

5. Education and social recognition of deaf people

Loss of hearing presents an enormous social handicap. People with hearing problems look no different than the average person. However, if they do not notice someone calling them, or do not respond to our greetings, many of us dismiss them as rude, never imagining that they are actually deaf. It is very unfortunate that such trifling matter in daily life causes them to lose respect. A blind person walking with white cane is easily recognizable, but hard-of-hearing people do not display any such signs.

We need to devise something for deaf people that indicates to others the fact that they have hearing problems. Similar to the white cane for blindness, a “signal” needs be created to demonstrate to others that “I cannot hear due to a loss of auditory function”. For example, how about a “beret cap with rabbit ears” as a charming signal?

Regardless of the method used, as we move towards an aging society with an increased population of hearing impaired individuals, we need to pay more attention to people with hearing problems.

We have described the past, present and future of hearing aids, with our own personal opinions interjected when appropriate. Sound is a stimulatory element indispensable to human life. With this in mind, we should give another thought to what is truly desired for the use of hearing aids.