AUDIO TECHNOLOGY IN THE UNITED STATES TO 1943 AND ITS RELATIONSHIP TO MAGNETIC RECORDING

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Abstract: This paper reviews the history of the development of audio technology in the United States from its origins in Alexander Graham Bell's telephone to the wartime work of the American electronics industry. It includes a comprehensive review of American contributions, including developments in electronic amplifiers, microphones, loudspeakers and phonographic, optical and magnetic recorders. The paper places these technical developments in the overall context of American developments in audio engineering during this period, and shows how social and economic factors retarded the growth of magnetic recording technology in the United States.

Introduction

The United States has played a central role in the development of audio technology. American scientists and engineers have been active in the development and commercialization of all aspects of sound recording, transmission and reproduction since the industry's foundation. Thomas Edison's phonograph and Alexander Graham Bell's telephone are the ancestors of all modern audio devices, and they and many other technical innovations call the United States home. This paper is a brief review of American contributions to audio technology prior to 1943.

The history of audio in this period can be divided into two roughly equal periods. The first, from 1876 to the end of World War I, is essentially the story of two technologies: telephone and phonograph. These technologies developed on separate paths, the telephone serving primarily as a method of communication, the phonograph as a method of entertainment. After World War I, the two technologies merged. The phonograph began to incorporate technology initially developed for the telephone, such as vacuum tubes and loudspeakers, changing from an acoustic device to an electronic one. In turn, telephone technology was adapted for entertainment purposes, most notably the systems that made sound motion pictures possible. Radio, an outgrowth of the telephone and initially developed to compete with it as a means of communication (the term "wire*less*" makes no sense without the context of a "wire" technology), became an entertainment medium with the invention of the concept of broadcasting in the 1920s. By 1943, audio devices constituted a large and integrated American industry.

Since this session has as its inspiration the anniversary of stereo magnetic tape recording, I should point out why there is no mention of magnetic recording in the above summary. In contrast to Germany, where magnetic recording found a ready market in the 1930s, that technology was by and large confined to the laboratory in the United States until very late in the period discussed in this paper. Americans made a number of contributions to this technology, which will be outlined below, but prior to 1943 magnetic recording was not a major industry in the United States.

The Telephone

The telephone, invented by Alexander Graham Bell in 1876, was the first audio device with major commercial potential. Bell's invention was relatively crude, yet by May 1877 his company was offering pairs of telephones for lease.[1] Bell Telephone was soon in competition with Western Union, the telegraph company, which made use of a telephone system invented by Elisha Gray. In an attempt to gain competitive advantage, Western Union contracted with Thomas Edison for research support. Edison invented the carbon button microphone in 1877, a device based on the variable resistance of carbon granules under pressure. This allowed the use of outside power in the system, considerably increasing the distance over which the voice could be transmitted. Still in widespread use in telephone applications, the carbon button was the first practical microphone.

The superiority of the carbon button put pressure on Bell. Bell answered by purchasing the patent of Francis Blake on a similar carbon transmitter in 1878, and the two companies began to compete to provide telephone service.[2] This competition proved to be brief, however. As a result of the stock market activities of Jay Gould, Western Union abandoned telephone activities in late 1879, signing an agreement to limit competition with Bell. As a result, Bell had an essentially monopoly position until the expiration of its patents in 1894. This was a period of relatively little technical innovation in telephone audio - the company sought to maximize profits by charging high prices for barely adequate service.

After the basic patent expired, Bell faced considerable competition from independent telephone companies. Bell attempted to maintain its position by buying patents from outside inventors and bring suit against competitors. However, in the increasingly anti-trust atmosphere of the period, courts proved reluctant to enforce these patents.[3] As a result, Bell turned to long distance communication to establish a competitive advantage. By offering better long distance service to more places, Bell sought to make its service more attractive.

This strategy had two major consequences. The first was an increased emphasis on research. The need for superior long-distance service technology increasingly led Bell executives to rely on their in-house engineering department to supplement the inventions purchased from outside inventors. This trend accelerated after Bell was taken over by J. P. Morgan in 1907. Theodore N. Vail was appointed president, and he set up the research division that was to eventually become Bell

Laboratories. As important as this was for the future development of audio, it pales in comparison with the other result of Bell's plan.

Tubes and Amplifiers

The second consequence of Bell's long-distance strategy was the commercial development of the vacuum tube amplifier, the foundation of the modern electronics industry. The major problem Bell faced in providing universal long-distance service was a lack of an electrical amplifier suitable for voice transmission over trans-continental distances in the United States. By the early years of the 20th century, improvements in telephone hardware, such as better switching equipment, more powerful transmitters and more sensitive receivers, no longer yielded increased range due to problems of crosstalk and self-induction.[4] Although an interesting example of the gains that can be made from gradually refining an existing technology, none of these devices were true innovations.

The one exception was the development of the loading coil by George Campbell of Bell Telephone and Michael Pupin of Columbia University in 1899. These coils significantly reduced audio distortion on long lines and so extended range. However, even with loading coils and the best equipment, range was limited to 1500 miles. While impressive, this was still considerably less than what was required to link the entire United States into one network.

Bell management recognized the need for a practical electronic amplifier, and they funded a research program. Bell scientists developed a variety of devices, though none proved practical. For example, in 1903 AT&T engineer Herbert Shreeve invented an electromechanical amplifier that worked for lines up to several hundred miles in length. However, the device was unsuitable for long-distance service since it introduced excessive distortion if connected in series.[5] Thus, when AT&T's chief engineer J. J. Carty announced in late 1909 that the company would demonstrate a transcontinental line in 1914, Carty was speaking on the basis of hope rather than knowledge.

As it turned out, Carty's prediction proved to be very nearly correct. AT&T connected New York and San Francisco on January 25, 1915 for regular service. The invention that made this connection possible was the de Forest Audion. Developed by the inventor Lee de Forest in the course of his wireless research, the Audion was the direct ancestor of the triode and so of all vacuum tube amplifiers. Although de Forest had invented the device in 1906, he initially used it only as radio signal detector, only later realizing its ability to amplify electrical currents. In October 1912, scientists at Bell became interested in the Audion and arranged for a demonstration. Impressed, they began to develop it.

The early Audion was not a reliable device, however, and it was the research of scientists at Bell Labs that transformed it into a viable amplifier. Bell Labs developed the first vacuum Audions and put them into service in 1913 on the New York-Washington line, followed by transcontinental service in 1915.

By the end of World War I, AT&T was mass-producing triode tubes that were reliable and uniform in quality. Quantities went from 200 per week in August 1917 to 25000 per week in November 1918.[6]

The vacuum tube amplifier solved Bell's long-distance problem and gave the company a considerable competitive advantage. As a result, the emphasis of research at Bell shifted away from audio to switching systems and network management. After World War I, the American telephone network changed only incrementaly in terms of the technology of its audio devices. Bell Laboratories continued to do research into audio, but the applications developed were for non-telephone products.

The situation of the vacuum tube industry was similar. Changes after 1920 were largely in manufacturing details, such as improved materials and better filament shapes, rather than any fundamental breakthroughs.[7] These changes did result in tubes that were more reliable and able to handle greater power levels, expanding the market for electronic products.

The primary American market for tubes prior to 1943 was in radio. Phonographs were a distant second; the Great Depression in particular depressed demand for electrical phonographs since most people could not afford to replace their old acoustic models. American tubes were simple in design and were standardized relatively early, basically by the mid-1920s. This is in marked contrast to British industry, which used complicated tubes due to the high royalty charged by the Marconi patent group. Marconi based the royalty on the number of tube sockets in the radio; complicated tubes reduced the number of sockets and so the royalty.[8]

Since American tubes were fairly simple, manufacturers were able to use mass production methods almost as soon as the industry was founded. As a result, manufacturing was dominated by makers of electric lamps, due to their mastery of the technology of glass forming.[9] General Electric, for example, became a major player in the tube market as a direct result of earlier research on electric-light manufacture. The large American domestic market for radios in the 1920s created a great deal of demand, and the combination of simple product, mass production, and competition soon resulted in low prices. As a result, American tubes were highly competitive in the world market.[10] This situation continued through 1943.

<u>Phonograph Recording</u>

The other major audio technology prior to World War I is the phonograph, invented by Thomas A. Edison in 1877. To construct this device he attached a stylus to a vibrating diaphragm which made a tracing on tinfoil wrapped around a cylindrical drum. Although a large body of mythology has grown up around this invention, in actuality it appears that the phonograph was a straightforward development growing out of the work Edison was doing at the time on telegraph signal recording devices.

Although the phonograph attracted considerable media attention, it did not have a great deal of commercial success. It appears that Edison was soon distracted by the development of his electric light system. That, combined with the relatively poor quality of the instrument's sound, meant it saw little use.

Interest in the phonograph revived in the late 1880s as a result of Emil Berliner's development of the disk phonograph. Edison continued to manufacture cylinder machines until the 1920s, but disks soon dominated the market. The cylinder was technically superior - it moved past the stylus at a constant speed, in contrast to the disk, where the stylus experienced a constantly decreasing speed as it moved toward the center of the record. Initially this made a difference, since most machines were used for personal recordings. However, as demand grew for pre-recorded material, the disk had a major advantage: it was easy to mass produce. One could easily make a casting and then stamp out an infinite number of identical copies. Cylinders, on the other hand, had to be recorded one by one. Edison eventually developed a method for casting cylinders, but he was forced to adopt the Berliner disk in 1912.

Edison's eventual failure was due to software rather than as hardware. He was primarily interested in sound quality, and constantly tried to make his recordings more lifelike. As a result, Edison machines had better potential sound quality than their competitors. For example, Ediphone dictating equipment was very competitive. Unfortunately for his company, this competitive position did not extend to recorded music. Edison was partially deaf, and since he approved every recording before release, recordings sounded odd because he simply could not hear certain frequencies. Edison also had poor taste in music, and he refused to deal with performers who had become popular with the public. As a result, he became less and less competitive in the market for recorded entertainment.

In contrast, competing companies like Columbia and Victor paid a great deal of attention to the content of their recordings. By maintaining catalogs of popular artists, these companies made it possible for individuals in remote areas to hear well-known artists, or for fans to experience a favorite song over and over. The phonograph, by separating the musical artist from his or her performance in both time and space, forever altered the nature of the musical experience. This alteration proved very popular, and the phonograph industry became quite large by the late 1910s.

The rise of radio in the early 1920s cut into the sales of records. Recording firms looked to improved technology to help their sales. In the early 1920s Bell Telephone laboratories undertook the development of two competing sound systems. One was sound on film under the direction of E. C. Wente. The other, under J. P. Maxfield and H. C. Harrison, focused on electrical recording and reproduction of phonograph recordings. The later team developed the Orthophonic method of recording, which was licensed to Victor and Columbia in early 1925. These electrical recordings could be used on both acoustic or electrical reproducers, and had superior frequency response and signal-to-noise ratio. The increased quality was due to the calculation in system terms of the nature of the recording process.[11] Electrical reproducing phonographs initially used moving coil styli - less expensive Rochelle salt piezoelectric styli became available in the mid-1930s. Recordings of this type on 78-rpm disks were the standard consumer phonograph in the United States until after World War II.

Western Electric, the manufacturing arm of the Bell system, took over development of the disk system in the mid-1920s and adapted it for use with talking motion pictures. The first use was with the film "Don Juan" in 1926, but only the sound track was recorded. In 1927 "The Jazz Singer" was the first full-length sound film recorded using this method. Known as Vitaphone, it was the first commercially successful motion picture sound system. However, due to competition from optical recording systems (discussed more fully below), the system was abandoned by 1932.

Drawing on the Vitaphone experience, Bell Laboratories developed a new phonograph system in the early 1930s. This new system used a vertical cut recorder, coupled with extensive pre- and post-equalization, to achieve significant improvements in signal to noise ratio.[12] This system was used in Hollywood and to record transcriptions of radio broadcasts until the arrival of magnetic tape after World War II.

A final note on stereo recording. Researchers at Bell Labs made stereo disk recordings as early as 1936, though commercial application did not come until the 1950s.[13]

<u>Sound on Film</u>

After the World War I, audio technology was increasingly driven by the needs of the entertainment industry. In particular, the radio broadcast and the motion picture fields were fertile grounds for technical innovations. Radio will be discussed in more detail later in the context of particular technologies, as will most of movie audio, but one aspect of motion picture sound was peculiar to that industry - optical recording. Also known as sound on film, this technology was used to record almost all of the sound films made before 1943 in the United States, but was very little used outside that industry.

Sound on film was developed in the U.S. as part of the Bell Labs efforts to cooperate with the Warner Brothers studio in developing talking motion pictures. Edward C. Wente was responsible for two of the innovations that made sound on film possible. In 1917 he had invented the condenser microphone that made accurate voice recording possible. He then went on to develop the light valve, a device that varied the amount of light going though an aperture in response to changing current. The light valve allowed a recording to be made on a strip of photographic film. This created a variable-density recording on the strip which could be played back by shining a light through the strip onto a photocell. The output of the photocell was then amplified to get the sound.

AT&T set up Electrical Research Products, Incorporated (ERPI) as a separate company in 1927 to exploit both the disk and sound on film recording methods.[14] ERPI's primary competitor was RCA Photophone Inc, set up in 1928 by RCA, General Electric and Westinghouse. This firm built a machine that used a variable-area method. The systems were otherwise functionally similar.[15]

Sound on film allowed for editing, especially for musical performance. There was also considerable work done on equalization to insure natural sound in the theater in playback. In the late 1930s the Motion Picture Research Council (founded in 1934) released an industry-wide standard test recording for each studio's sound characteristic. This equalization was designed to save theatre owners the expense of adjusting to each film's response curve.[16]

There were a variety of detail improvements during the 1930s, including fine grain film by Du Pont and Eastman, intermodulation tests to allow testing for noise sources developed by RCA, and improved filters to reduce signal-to-noise ratios used by various studios. The first stereo and surround sound film was released in 1939, Disney's "Fantasia."[17] Sound on film remained the standard recording medium for motion pictures through 1943

Microphones

The rise of the radio and motion picture industries after World War I created a demand for more efficient microphones. The carbon button microphone developed by Edison was adequate for telephone applications where only speech was transmitted, but lacked the frequency response for song and music. As a result, experimenters developed a variety of microphones prior to 1943. These devices are grouped by type and described below.[18]

-Conductor in a magnetic field-

The ribbon microphone was invented by E. Gerlach in 1925, but a practical commercial version was not developed until 1931 by Harry F. Olson of RCA. This microphone found wide use in radio and motion picture recording, in large part due to its directional characteristics.

-Piezoelectric-

Although the piezoelectric effect has been studied since the early 19th century - Becquerel published on the subject in 1820 - the first description was published in 1919 in the United States of the effect's possible applications to audio. Commercial manufacture of audio microphones had to await the development of the "bimorph" Rochelle salt crystal transducer by C. Baldwin Sawyer of Brush Laboratories in the early 1930s. Brush went on to manufacture microphones and phonograph pickups based on the Rochelle salt crystals.

-Condenser-

The first wide frequency range condenser microphone was developed by E. C. Wente in 1917 at Bell. Work continued during the 1920s and 30s on reducing the size of the microphone and dealing with the distortion caused by the cavity external to the diaphragm. This led to the development of very small condenser microphones suitable for motion picture use, for example the microphone developed by Harrison and Flanders in 1932 at Bell Labs. This microphone was quite small and provided uniform response up to 10,000 Hz.

Loudspeakers

Ernst W. Siemens described the first diaphragm controlled by an electromagnet used as a sound producing device in 1874, though it appears that he intended it as a telegraph sounding device rather than an electrical transducer. The first description of a moving-coil transducer was by Charles Curtis and Jerome Redding of Boston in their 1877 patent application. They and a variety of other workers attempted to develop a practical loudspeaker over the next forty years. The first widely successful device was designed by Pridham and Jensen of Magnavox in 1915. Moving-coil loudspeakers similar to their design became the dominant reproducer technology in the United States through 1943.

C. W. Rice and E. W. Kellogg of General Electric published the first comprehensive treatment of moving-coil loudspeakers. Their theoretical treatment showed how to design systems for minimum distortion and flat frequency response. Building on these ideas, a number of American firms developed sophisticated sound systems for motion picture theatres during the 1930s. By the late 1930s, these systems were capable of frequency response and dynamic range unsurpassed for the next fifty years.

The other major loudspeaker technology explored during this period was the electrostatic. Due to various theoretical and practical design problems, this type of speaker enjoyed no commercial success.

Magnetic Recording

Oberlin Smith, inventor and owner of the Ferracute Machine Company, first conceived of using electromagnetism to record sound in 1878, only a few months after he visited Thomas Edison's Menlo Park laboratory and saw the newly invented phonograph. Smith performed a number of experiments in an attempt to prove his concept, but due to financial pressure and the demands of his other business interests, he was unable to develop a working device.[19] He eventually published his ideas in 1888, hoping someone else might be able to perfect his concept.[20] Several other inventors patented recorders based on electromagnetic principles at about the same time, but none of them was able to build a working machine either.

A functional magnetic recorder was eventually built in 1898 by a Danish inventor, Valdemar Poulsen, whose work appears to have been independent of Smith's. Poulsen demonstrated his invention, which he called the "telegraphone," at the Paris International Exhibition in 1900, garnering a gold medal and a great deal of coverage in the international technical press. On the strength of this success, Poulsen set up manufacturing firms in both Denmark and the United States. The American firm was the primary attempt to exploit Poulsen's invention. Incorporated as the American Telegraphone Company, the firm purchased Poulsen's patents and set up a factory. Due to poor management, American Telegraphone produced fewer than a thousand recorders over the next twenty years, fell in to receivership in 1920, and was finally dissolved in 1944. After American Telegraphone entered receivership, several large corporations, including Westinghouse and General Electric, purchased telegraphones and subsequently patented inventions related to magnetic recording.[21] However, no commercial products resulted from these inventions.

The Bell system initiated research into magnetic recording program in 1916 or 1917, after engineers at Western Electric obtained a telegraphone for experimental work.[22] This led to four patents relating to signal multiplexing and to sound delay for public address systems in large auditoriums.[23] But after the last of the four patents was filed in December 1920, there is no evidence of any further work on magnetic recording at Bell until January 1930, nor is there any evidence of any commercial products resulting from these patents.

During the 1920s, there was relatively little research activity related to magnetic recording anywhere in the United States or in Europe. Poulsen had abandoned magnetic recording for the more profitable area of radio by 1904, and no telegraphones were built in Europe after 1913 at the latest.[24] The large American firms discontinued their research by 1922, and only a few individual inventors persisted, devoting their efforts unsuccessfully to developing a magnetic recording-based system for sound motion pictures.[25] All active commercial ventures involving magnetic recording in the 1920s were European. The only significant development in the United States during this period was the development of high frequency bias by Carlson and Carpenter at the Navy's wireless telegraphy laboratory in Washington in 1920. This method of improving the quality of recordings was not commercialized, since no American firms were making recorders at the time, and high frequency, or AC-bias, had to be independently rediscovered in the late 1930s before it saw widespread use.

When Bell Telephone Laboratories took up the question of magnetic recording in 1930, the motive was not pressing outside competition. Rather, it was pressure from outside firms trying to interest AT&T in some form of telephone answering device that served as the immediate inducement for Bell Labs to undertake further work on magnetic recording. A number of different companies contacted AT&T during the 1920s, and almost all of their products were referred to Bell Laboratories for evaluation.[26] The majority of those systems were based on phonographic recorders, but Bell also tested a number of telegraphone (i.e. magnetic) recorders.

At first, Bell engineers rejected all of these devices, citing their poor performance as justification. Eventually, however, they suggested that Bell Laboratories' recent innovations in phonograph and theater sound systems could be applied to the problem of telephone recording. As a result, in late 1929 the director of Bell Labs, Dr. Frank B. Jewett, concluded that technical reasons alone no longer sufficed for rejecting telephone recorders.[27] He hired Dr. Clarence Hickman and assigned him a small budget to investigate magnetic recording in general.[28]

Hickman started his research on January 4, 1930. By the end of 1930, Hickman had considerably improved the recording clarity of his machines. The combination of alloy steel tape and a new recording head resulted in markedly better sound.[29] Hickman demonstrated a prototype to lab personnel and several patent attorneys on December 31, 1930, and those who listened "seemed to be much impressed."[30] Subsequently, Hickman claimed that the background noise for this machine was less than for a phonograph, a claim that, if true, would make his magnetic recorder the best in the world at the time.[31]

Over the next six years, Hickman continued to work on projects related to magnetic recording. He was involved in the design of a number of experimental systems, and his work led to a total of eight patents. Eventually, as the project turned away from research and development and more towards the design and building of prototypes for field testing, Hickman was reassigned to other projects.[32] Prior to his departure from the magnetic recording project team, however, he was intimately involved in the design and construction of the Bell Labs prototype magnetic recording telephone answering machine. Built in early 1934, this apparatus functioned in a fashion identical to that of a present-day answering machine, responding to a telephone call with a prerecorded message and then recording the message left by the caller.

Despite Bell Laboratories' interest in sound recording, production of a working answering machine, and a demonstrated desire to commercialize the products of laboratory research, the Bell system delayed in offering an answering machine to its customers until the early 1950s, almost twenty years after the production of a successful prototype. This delay was not due to a faulty perception of demand on the part of Bell and AT&T executives; memoranda from the 1920s and 1930s refer constantly to customer requests for recorders and outside companies trying to interest Bell in their own devices.[33] Nor is it due to a lack of confidence in their technology. Contemporary reports of field trials show that Bell had developed magnetic recording to the point of practical application. In fact, evidence suggests that Bell had what was probably the best magnetic recording technology in the world through most of the 1930s, until the development of machines that used AC-bias after 1938. A German recorder Bell engineers examined in 1931 was inferior to Hickman's experimental model, and later tests of Bell equipment gave results as good as phonograph recording. Moreover, during a 1935 visit to Germany a Bell representative examined commercial magnetic recorders made by Lorenz and found them to be inferior to Bell's efforts.[34]

Given Bell's successful experiments and the evidence of Bell's superior technology, why was there little or no attempt to commercialize the developments of Bell's engineers? Quite simply, through concerted effort, upper level executives at AT&T sought to suppress the commercial exploitation of magnetic recording for ideological reasons stemming from the corporate culture of the Bell system. Internal memoranda reveal that AT&T's management worked to dampen outside demand for recorders and to limit the use of magnetic recording within the Bell system to selected areas.

Why? The reason was very simple: Management feared that the availability of a recording device would make customers less willing to use the telephone system and so undermine the concept of universal service. This fear is explicit in the memos that were written discussing the possibility of commercializing magnetic recording. The fear took two forms. First, if conversations became matters of record in the same way as letters or other contracts, managers felt that customers would abandon the telephone for critical negotiations and return to the mails, where a slip of the tongue would not prove fatal.[35]

Second, if conversations could be recorded, matters of an illegal or immoral nature, which some executives estimated made up as much as one third of all calls, would no longer be discussed by phone.[36] The net result of this perceived loss of privacy would be a great reduction in the number of calls and a reduction in the trust individuals placed in the phone system, meaning a loss in both revenue and prestige for AT&T. Although one might expect that managers would stress the economic half of this equation, in fact they paid far more attention to the question of trust and image. AT&T during this period had constant public relations problems, largely due to anti-trust investigations. Thus, that magnetic recording might create a major upset with only a minor gain for a few customers who could afford to have their calls answered automatically was simply not acceptable for managers concerned with preserving AT&T's good name.

This desire to control the nature of the telephone system and to prevent the attachment of devices like telephone recorders that were outside system control was an integral part of corporate culture at AT&T. As Leonard Reich has pointed out, the focus at the Bell system since 1907 had been on increasing the control of the central authority.[37] To provide universal service at a superior level of quality became AT&T's formula for corporate prosperity. Such quality service, AT&T management believed, could only be insured if AT&T had control over every part of the telephone network and everything attached to it. Any technical innovation that might affect service was treated with suspicion; magnetic recording was no exception. AT&T had consistently fought against the attachment to its circuits of devices it did not control. Magnetic recorders, which could be easily connected to telephones without the AT&T's permission, were anathema to Bell's executives.

Thus, Bell Laboratories and AT&T, although developing in the laboratory sophisticated magnetic recording systems, effectively suppressed commercial development that went against the firm's own interests. Although the company did publish articles in its technical journals about its research, these articles reveal a consistent pattern: Those applications of magnetic recording useful to AT&T's central offices were shown; those useful to individuals were not. AT&T did exhibit magnetic recorders at both the 1933 Chicago Century of Progress Exhibition and at the 1939 New York World Fair, but requests by AT&T subsidiaries to exhibit those machines elsewhere were denied, and individuals who wrote to Bell Labs asking about the machines were told that AT&T had no plans for further commercial exploitation, even though in actuality research was constantly going on at Bell into various applications. As a result of this suppression by AT&T, the commercialization of magnetic recording in the United States lagged behind Germany.

Until the late 1930s, Bell Laboratories was the only American organization researching magnetic recording. In 1935, the German magnetic recording engineer Dr. Semi Joseph Begun emigrated to the United States. He later set up a small partnership to manufacture a recorder of his own design. Marketing efforts were unsuccessful, and in 1938 he took a job with the Brush Development Company, a manufacturer of piezoelectric crystals. Begun persuaded Brush management to expand into the magnetic recording field. Brush then manufactured Begun's Soundmirror, a high-quality endless metal tape loop recorder with a short (one minute) recording time intended for voice training. Western Electric, Bell Telephone's manufacturing arm, marketed a similar machine based on Hickman's inventions called the Mirrorphone at roughly the same time. These were the first commercial magnetic recorders made in the United States since the early 1920s.

The only other major research effort in this period was that of Marvin Camras at the Armour Research Foundation. Camras developed an improved wire recorder design, which Armour was just getting ready to commercialize when the United States entered World War II in late 1941. Camras's machines incorporated AC-bias, and over 5000 were purchased by the American military during World War II.

In contrast to Germany, there was little market for magnetic recorders in the United States prior to World WAr II. This primarily due to the fact that the two major markets that existed in Germany had no parallel in America. The market for magnetic recording dictation equipment was greatly aided by its ease of connection to telephone circuits. As noted above, this market did not exist in the United states due to the opposition of Bell Telephone. As to the other major market, radio broadcasting, the major American networks had a strong bias towards live performance, and since they were the only ones who could afford the expense of the magnetic recorders of the period, that market did not develop in the United States until after World War II. As a result, the commercialization of magnetic recording was well behind that in Germany at the beginning of World War II.

After Pearl Harbor and America's entry into the war, Bell engineers who had worked on magnetic recording went on to serve in wartime in research and development posts related to magnetic recording, and Bell Laboratories manufactured a number of recorders for the military during the war. However, the bulk of wartime work on magnetic recording was done by other organizations, most notably the Armour Research Foundation and the Brush Development Company. The technological lead Bell Laboratories and AT&T had developed in the 1930s and the suppression of magnetic recording they had engineered were shattered by the events of the 1940s.

Military requirements created the demand for magnetic recording products that had been absent in the United States before 1941. The thousands of recorders Bell and others built for the American military in World War II led directly to industry and consumer demand for magnetic recorders and the manufacture of hundreds of thousands of magnetic recorders in the years just after the war. However, those recorders were not built using technology developed by Bell Labs. Wartime research funded by the United States government and conducted by Armour and Brush resulted in the movement of a wide variety of new technologies out of the laboratory into production. These innovations included ferrite tape, AC-bias, and improved magnetic materials. After the war, these developments were combined with captured German technology to form the basis for the postwar American boom in magnetic recording.

Conclusion

The American audio industry has made significant contributions to the development of all aspects of audio technology. By 1943, American consumers enjoyed access to a wide variety of products, and the electronics industry that had grown up around consumer radio was deeply involved in the war effort. Although stereo magnetic recording was first demonstrated in Berlin in 1943, it was to be the American audio industry that would commercialize that invention in the post-war world.

1.Leonard S. Reich, The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926, Cambridge University Press, Cambridge, 1985, p. 132.

2.Reich, p. 133-34.

3.Reich, p. 136-37.

4.Reich, p. 144.

5.Reich, p. 157.

6.Attila R. Balaton, "Tube Manufacturing at Western Electric: The WE 300B," J. Audio Eng. Soc., Vol 37, No. 11, 1989 November, p. 949-50.

7.Balaton, p. 950-54.

8.Jerome Krause, "The British Electron-Tube and Semiconductor Industry, 1935-62," Technology & Culture 9, (October 1968), p. 547-48.

9.Kraus, p. 545.

10.Reich, p. 86-88.

11.John G. Frane, "History of Disk Recording," J. Audio Eng. Soc, Vol. 33, No. 4, 1985 April, p. 263.

12.Frane, p. 265-66

13.Frayne, p. 269.

14.John K. Hilliard, "A Brief History of Early Motion Picture Sound Recording and Reproducing Practices," J. Audio Eng. Soc., Vol. 33, No. 4, 1985 April, p. 271-72.

15.Hilliard, p. 272

16.Hilliard, p. 274-76.

17.Hilliard, p. 277.

18.This section is drawn from Ivor D. Groves, Jr., ed., Acoustic Transducers, Hutchinson Ross Publishing Company, Stroudsburg, Pennsylvania, 1981.

19.James W. Gandy, "Bridgeton: The Birthplace of Magnetic Recording," South Jersey Magazine 18 (Summer 1989): 8-12.

20.Oberlin Smith, "Some Possible Forms of Phonograph," The Electrical World 12 (September 8, 1888): 116. An examination of Smith's other papers indicates that although this article was published in 1888, all of the research was done prior to 1879.

21.U.S. Patents 1,664,243 and 1,883,907.

22.It is possible that the telegraphone was left over from tests done in 1911-12 to determine if an improved telegraphone built by the American Telegraphone Company was suitable for telephone use, though not likely.

23.U.S. Patents 1,358,053; 1,365,470; 1,465,732; and 1,624,596.

24.After 1914, customers in Europe were supplied by the American Telegraphone Company. For a description of Poulsen's career in radio and a history of the development of the Poulsen arc transmitter, see Hugh G. J. Aitken, The Continuous Wave: Technology and American Radio, 1900-1932 (Princeton, N.J., 1985).

25.See, for example, Harry E. Chipman, U.S. Patents 1,480,992; 1,612,359; 1,832,097; 1,883,559; 1,883,560; 1,883,561; 1,883,562 or Edward Everett Cothran, U.S. Patent 1,588,706.

26.For example, see the correspondence between AT&T and the Dictaphone Corporation in folder 74-07-03-03, AT&T Archives, which contains a number of references to examination of the equipment of Dictaphone and others by Bell engineers.

27.F. B. Jewett, "Development of Telephone Speech Recording Equipment," August 9, 1929, folder 74-07-03-04, AT&T Archives. Jewett was the head of Bell Laboratories from its founding in 1925 until 1940.

28.Hickman, trained as a physicist (Ph.D., Clark University, 1920), had had a rather interesting career prior to joining Bell Labs. He worked with Dr. Robert Goddard on rocket development work in 1918. After receiving his Ph.D., he went on to do research for the Bureau of Standards and the U. S. Navy Yard in Washington. When he joined Bell Labs, he had been working since 1925 doing acoustics research at the American Piano Company, a manufacturer of player pianos. During World War Two, he headed the NDRC Rocket Development committee, due to his prior work with Goddard. Winfield Scott Downs and Edward N. Dodge, Who's Who in Engineering (New York, 1959), p. 1108; Press Release from Bell Telephone Laboratories, January, 1946, Box 96-06-16, AT&T Archives.

29.Laboratory Notebook of Clarence Hickman (hearafter "Notebook"), AT&T archive, pp. 54, 57.

30.Notebook, p. 59.

31.Notebook, p. 61. To my knowledge, no other magnetic recorder maker from this period claimed performance approaching that of a standard phonograph.

32.Notebook, p. 137; U.S. patent 2,086,130. Hickman's last patent filings and his last notebook entries related to magnetic recording date from mid-1936. He continued to work at Bell labs until 1950, but never again on magnetic recording.

33.See, for example, "Memorandum for Mr. E. H. Colpitts, Assistant Vice President," August 8, 1929, and R. H. Colpitts to H. Nagatomi, July 25, 1932, both in Case 35825-173, AT&T Archives.

34.R. F. Mallina to C. N. Hickman, May 16, 1935, Case 20872, AT&T Archives. Mallina went on to indicate that he planned to visit to AEG to see its recorder, but no record of that visit, if it took place, is in the case file. Other sources from the period indicate that the AEG recorder at this time was considerably inferior to those of Lorenz.

35.B. Gherardi, (File copy of Circular Letter), November 26, 1930, Folder 74-07-03-03, AT&T Archives. This argument is repeated in a number of other documents in this file over the next ten years.

36.Hearing before the Committee on Patents, United States Senate, Seventy-Second Congress, 1st sess., on S. 1301, A Bill to Renew and Extend Certain Letters Patent, March 10, 1932, (Washington, D. C., 1932), p. 30.

37.Reich, p. 142.

Addendum to Clark "Audio Technology in the United States to 1943 and Its Relationship to Magnetic Recording", AES Preprint 3481.

Clark's contention that AT&T/Bell Telephone Labs suppressed publication of important research that they had done on magnetic recording is supported by my paper "AC Bias at Bell Telephone Laboratories 1936...1939" (http://aes.org/aeshc/pdf/mcknight_ac-bias-at-btl-1936-1939.pdf). This paper tells of an interview with Wooldridge in 1976, that I learned of quite by accident. That interview describes work he did at BTL between 1936 and 1939, that was not published until 1946 – and then in a rather obscure footnote

Also of interest: The magnetic recorder exhibited by AT&T at the 1939 New York Worlds Fair did in fact use Wooldridge's research, including ac bias. This recorder is shown by Begun in his 1949 book "Magnetic Recording", and I have reproduced it in my paper, above.

Jay McKnight
2011-12-05