from E. Thompson, The Soundscape of Modernity, 2002.

CHAPTER 6 ELECTROACOUSTICS AND MODERN SOUND, 1900–1933

> [A] new factor has come strongly into the picture, and I believe that it will call for some radical revisions of our criteria for best acoustics. I refer to the electrical reproduction of sound.[1]
>
> Edward W. Kellogg, General Electric Research Lab, 1930

I INTRODUCTION: OPENING NIGHT AT RADIO CITY

It was cold and rainy in New York on the night of 27 December 1932, but that didn't prevent a large crowd from gathering at the corner of 50th Street and 6th Avenue. Six thousand had come to witness the grand opening of Radio City Music Hall, and many others turned out hoping to catch a glimpse of the rich and famous as they entered the building. The doors opened at 7:30 P.M., and those fortunate enough to hold tickets entered the theater through a narrow hallway, then emerged into the foyer, which stretched 140 feet toward the grand staircase at its far end. (See figure 6.1.) None of the austere, technologically pure modernism of the PSFS Building was to be found here. Instead, Radio City Music Hall was flamboyantly Moderne, an Art Deco dream in which "Beaux-Arts monumentality is wedded to jazz cubism and the Hollywood stage set."[2] The Music Hall offered its guests a glimpse of "sophisticated life lived among skyscrapers,"[3] and on opening night the sophisticates themselves were out in force.

An NBC radio announcer was stationed in the lobby and he described to distant listeners the arrival of John D. Rockefeller, Jr., whose wealth had funded the new Music Hall as part of Rockefeller Center. Former New York governor Al Smith soon followed, as did aviatrix Amelia Earhart, comedian Charlie Chaplin, prize-fighter Gene Tunney, conductor Leopold Stokowski, and thousands of others. Some of the stars stopped by "to say a word to the radio audi-

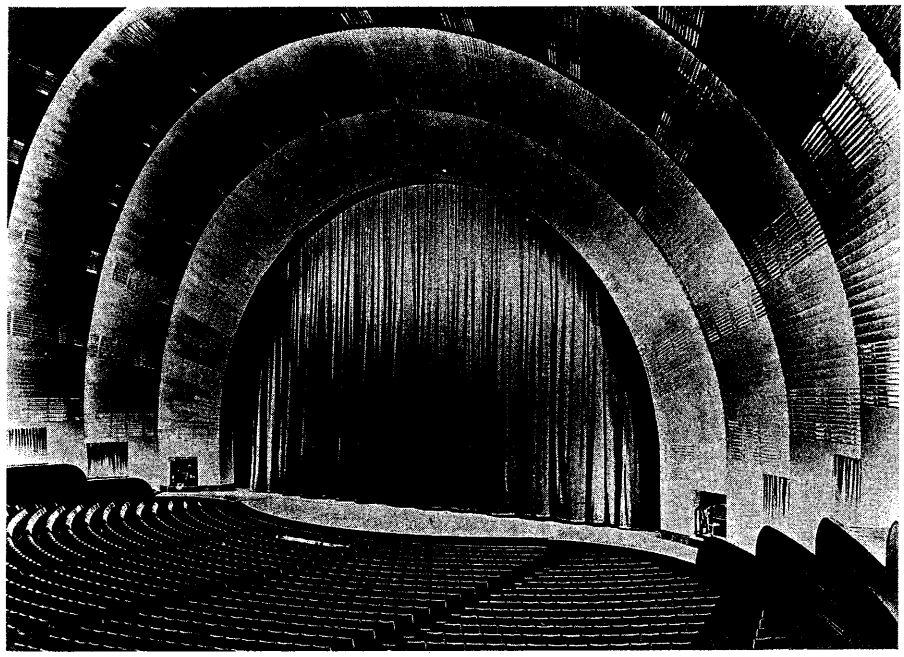
6.1
Rockefeller Center, Radio City Music Hall Lobby, view from balcony, c. 1934. The ornate interior of Radio City Music Hall, which contrasts sharply with the austere modernism of the PSFS Building, was characterized as an Art Deco dream in which "Beaux-Arts monumentality is wedded to jazz cubism and the Hollywood stage set." Photograph, n.d., Museum of the City of New York, The Wurts Collection.

ence" on their way in, and Mayor-elect John O'Brien went on for so long he had to be pulled away from the microphone.[4] The hubbub of arriving guests, the noise and confusion of the traffic outside, the crowd of onlookers, and the police overseeing them were described to millions of listeners far removed from the event. Those distant listeners were vicariously present through the modern machinations of electroacoustic technology.

The show itself was not broadcast, so the radio audience was left behind in the lobby as the guests moved into the auditorium and found their seats. Their attention was immediately drawn to the series of immense, telescoping arches that made up the walls and ceiling of the auditorium. (See figures 6.2 and 6.3.) "The hall has a mighty, swift sweep," architectural critic Douglas Haskell explained. "It has focus and energy. The focus is the great proscenium arch, over sixty feet high and one hundred feet wide, a huge semicircular void, filled, at the moment, by the folds of a golden curtain. From that the energy disperses."[5]

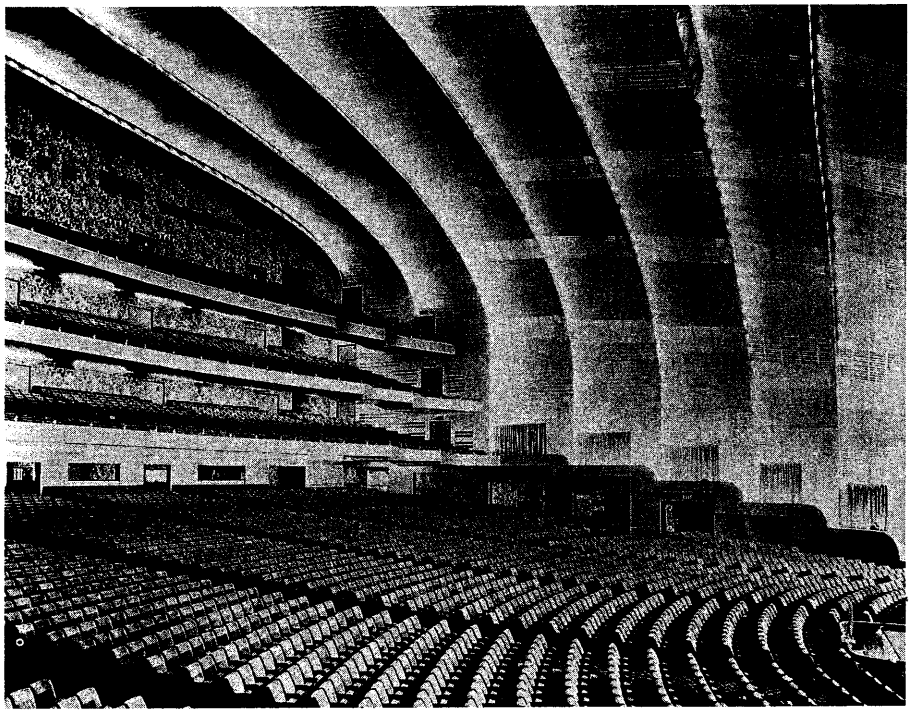
The golden curtain finally rose at 9:00 P.M., or, rather, it danced. Thirteen motors controlled its folds and contours as the fabric undulated to the music of Rimsky-Korsakov in a "Symphony of the Curtains." Patriotic music from the mighty Wurlitzer organ followed; the acrobatic Wallenda Troupe tumbled; Fräulein Vera Schwartz sang Johann Strauss's "Liebeswalzer"; the Tuskegee Institute Choir offered gospel tunes amidst "clouds of Wagnerian steam"[6]; Ray Bolger clowned; forty-eight nimble-legged "Roxyettes" kicked; the Martha Graham Ballet interpreted a Greek tragedy; and five hours after the curtain had risen, the classic schtick of "old-time"[7] vaudeville comedians Joe Weber and Lew Fields finally brought the inaugural program to a close.

Critics subsequently panned the show for being long and dull, and the *New York Times* condemned it as the "product of a radio and motion-picture mind."[8] The remark was a gibe at the show's producer, Samuel "Roxy" Rothafel, who was renowned for managing deluxe motion picture palaces in which elaborate live stage shows (regularly broadcast on radio) preceded the presentation of the films.[9] While the *Times* blamed radio and motion pictures for the dramatic failure of the spectacle, those same technologies were equally responsible for its acoustical success. For, in spite of the unprecedented size of the Music Hall, reviewers unanimously concluded that everyone could hear "quite well, even from the seats furthest from the stage."[10] What the audience heard, however, was not the natural voices of the performers, but their reproduction as rendered by loudspeakers concealed behind the golden grilles of the magnificent ceiling arches. Radio City Music Hall was wired for sound, and no one seemed to mind.



6.2
Radio City Music Hall, view of stage, c. 1933. Although the shape of the proscenium suggests expanding waves of sound, the huge arches were actually made of sound-absorbing plaster. Loudspeakers were hidden behind the grilles that were integrated into the arches. Photograph, n.d., Museum of the City of New York, Theater Collection.

6.3
View of Radio City Music Hall 6,200-seat auditorium, c. 1933. The reverberation of the vast auditorium was minimized by the use of sound-absorbing plaster for the ceiling arches and by a highly absorptive covering on the rear wall, ensuring clear and distinct reception of sound throughout the hall. Photograph, n.d., Museum of the City of New York, Gift of Charles B. MacDonald, 50.326.44.



The deployment of microphones and loudspeakers into the soundscape occurred gradually but persistently over the course of the 1920s. Devices first developed in scientific laboratories as tools to study sound now became mass-marketed products that provided listeners with an expanding array of new acoustical commodities. In the home, electrically amplified phonographs and radio loudspeakers became increasingly popular sources of aural entertainment. Public address systems and talking motion pictures transformed public spaces for listening. By 1932, it was customary for people to gather and listen to loudspeakers broadcasting reproduced sound; this is why the electrically generated sound in Radio City Music Hall was so unremarkable.

That sound would not have been satisfactory, however, if the new technology had not been deployed in tandem with that more traditional tool of acoustical control, sound-absorbing building materials. The dramatic arches that constituted the envelope of the auditorium may have looked like expanding waves of sound energy, but they were, in fact, constructed of sound-absorbing plaster. That plaster minimized the reverberation in the hall and ensured that each member of the audience enjoyed distinct and direct reception of the sound signals emanating from the loudspeakers.

In its powerful combination of architectural and electrical control over sound, Radio City Music Hall represents a culmination of the modern soundscape. Within its walls, the age-old "mysteries of the acoustic" were finally and fully revealed by modern acoustical technologies. A forlorn architect had evoked those mysteries in a letter to Wallace Sabine many years before, but that frustration was now replaced by a pervasive sense of mastery. Roxy, who ruled over Radio City as absolutely as Henry Higginson had over Symphony Hall, predicted that the acoustics of his hall would be "perfect,"[11] and no one questioned his confidence in this result. Just as Roxy's confidence contrasted with the tentative attitude of those who first gathered to listen in Symphony Hall, so, too, did the sound of Roxy's hall differ from its turn-of-the-century predecessor. By returning to performance spaces, and by charting the transformations that occurred within them, the architectural and electrical construction of this new modern sound will be fully elaborated.

Radios, electrically amplified phonographs, public address systems, and sound motion pictures transformed the soundscape by introducing auditors not only to electrically reproduced sound but also to new ways of listening. As people self-consciously consumed these new products they became increasingly "sound conscious,"[12] and the sound that they sought was of a particular type. Clear and

focused, it issued directly toward them with little opportunity to reflect and reverberate off the surfaces of the room in which it was generated. Indeed, the sound of space was effectively eliminated from the new modern sound as reverberation came to be considered an impediment, a noise that only interfered with the successful transmission and reception of the desired sound signal.

But this modern sound was not simply the outcome, or output, of new electroacoustic technologies; it was also heard in rooms for live performance that were not wired for sound. Well before application of the new electrical technologies had become widespread, acousticians had begun to promote new acoustical criteria that minimized the significance of reverberation and emphasized the direct transmission and clear reception of sound. The modern spaces that embodied these new standards—from the Eastman Theatre to the Hollywood Bowl—thus produced sounds much like those increasingly being reproduced via microphones and loudspeakers.

Most Americans encountered this modern sound most frequently, however, in auditoriums that were wired for sound, particularly in the sound motion picture theaters that proliferated after 1927. The motion picture industry played a crucial role in defining and disseminating the new sound, and the evolution of acoustical technologies in theaters and studios demonstrates how architectural acoustics and electroacoustics gradually merged. Physically as well as conceptually, the distinction between sound in space and sound signals in circuits fell away, as acousticians and sound engineers sought to achieve ever greater degrees of control.

As sound engineers grew adept in the new techniques of electrical recording, they learned to employ those techniques to create artificially the sound of space that had been banished from the studio itself. The "virtual space" (as we might call it today) that they created was not, however, associated with the real architecture of studio or theater, but instead represented the fictional space inhabited by the characters in the program being broadcast or filmed. The sound track itself constituted a new site in which the sound of space could be constructed and manipulated to a degree not fully attainable in the architectural world. Even so, the desire for direct, nonreverberant sound was pervasive, and sound engineers exercised their new power with discretion, creating distinctive virtual spaces only occasionally as "sound effects."

The modern soundscape that resulted from all these developments in the science and practice of architectural acoustics and electroacoustics was, by 1930, ubiquitous. It differed so significantly from its predecessor that the very foundation of architectural acoustics had to be reformulated in order to characterize

accurately the new aural environment. Wallace Sabine's reverberation equation had constituted the first significant and successful effort to control the behavior of sound in rooms, and it had stimulated an extensive development of the science and technology of architectural acoustics in the decades that followed. By 1930, the success and extent of that development were such that Sabine's equation no longer described the modern world of rooms filled with modern sound. Sabine's formula was revised, and with this revision, the transformation of the soundscape was complete.

II Listening to Loudspeakers: The Electroacoustic Soundscape

In 1876, Alexander Graham Bell's telephone announced the arrival of electrically reproduced sound. This new, technologically mediated sound immediately reconfigured traditional relationships between sound and space.[13] The telephone—like the telegraph before it—was heralded for "annihilating" space and time, by effectively eradicating the physical distance between people who wished to communicate, and by transmitting their communications across space virtually instantaneously.[14] Yet, geographic space was not the only kind of space annihilated by the telephone.

When two people converse face-to-face, the sound is modified as it passes from speaker to listener. This modification is the result not only of the distance between them (which affects the volume or loudness of sound), but also by the acoustical character of the space that they inhabit (which affects the quality of sound). Little such spatial modification occurred when people began to converse over the telephone. In order for a telephone conversation to be audible, the transmitter had to be held close to the speaker's mouth and the receiver adjacent to the listener's ear; thus telephonic sounds did not fully occupy architectural space as did the sounds of an ordinary conversation.[15] It was as if the telephonic conversants were speaking directly and intimately into each others' ears, oblivious to not only the distance between them, but also the space around them.[16] When the sound of that space did intrude (for example, with a public telephone in a reverberant location), it was perceived as unwanted noise, much like the electrically generated disturbances and distortions that similarly interfered with the intelligibility of the speech signal. Telephone engineers modified their circuits to eradicate the electrical noise; spatial noise was eliminated by the construction of the soundproof and nonreverberant space of the telephone booth.[17]

Thomas Edison's phonograph appeared just a year after Bell's telephone. Like the telephone, the phonograph introduced people to sounds that had been severed from architectural space, and it taught them to distinguish between desired sound signals and unwanted sounds or noises.[18] Early phonograph recordings were made by speaking directly into the large end of a conical horn. The sound vibrations set in motion a diaphragm positioned at the apex of the horn, and a stylus mounted on the vibrating diaphragm cut an undulating groove into a wax cylinder that revolved beneath it.[19] Since the sound of the voice was channeled directly into the horn, there was little opportunity for the surrounding space to modify that sound before it was recorded onto the record. For phonographic reproduction, the undulating groove of the record was passed under a stylus whose motions were transmitted to a reproducing diaphragm. The moving diaphragm set the surrounding air in motion, re-creating the sound of the original source. The acoustical output of the earliest phonographs—like the electroacoustic output of the telephone—was weak, and listeners often listened through narrow tubes that carried the sound directly into their ears. Thus, here, too, the room in which the listener listened played little role in shaping the character of the sound heard. From start to finish, phonographic sound was isolated as much as possible from any spatial context.

As Bell, Edison, and their colleagues and competitors worked to improve the quality of telephonic and phonographic sound signals and to minimize the interfering effects of noise, others were exploring the technology of radio.[20] At the turn of the century, those who listened to radio transmissions relied upon electroacoustic headsets to render audible the faint signals captured by their homemade receiving apparatus. These headsets, like telephone receivers, converted the electrical signal into sound vibrations and transmitted that sound directly into the listeners' ears. The headsets were identical to those worn by telegraph operators; indeed, early radio was known as "wireless telegraphy" and the signals received were simply the dots and dashes of Morse code. But when continuous wave transmission became possible, the sounds of speech and music were soon being transmitted across the ether and into the ears of eager listeners.[21]

Susan Douglas has examined the different modes of listening associated with radio technology as it evolved over the course of the twentieth century. From the turn of the century until around 1925, the mode was known as "DX-ing," or listening for distant transmissions. The goal was to see "how far" one could hear. Radio listeners, typically boys or young men, designed and manipu-

lated their homemade wireless sets to tune in to distant transmissions. By listening carefully through their headsets, they learned to detect the faint radio signals amid the ever-present static or electromagnetic noise. This kind of listening celebrated the same annihilation of distance that had been heralded with the telephone, and, as with the telephone and phonograph, the sound of the space occupied by the listener played little if any role in the experience. DX-ing also required a mode of listening that kept the distinction between signal and noise constantly in mind.

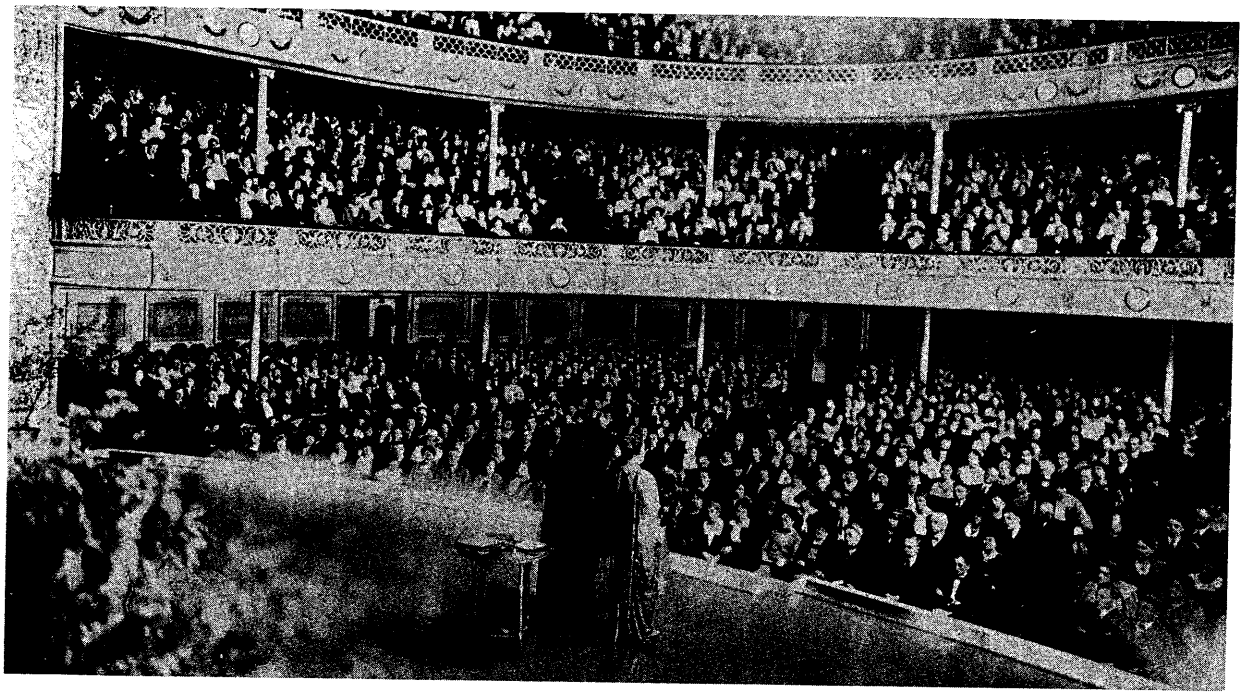
While the telephone remained a device for person-to-person conversation and therefore maintained its intimate contact with users' mouths and ears, radio and the acoustical phonograph were soon modified to allow their re-created sounds to fill the rooms in which they were heard, enabling communal listening. For the phonograph, this was accomplished by the use of a reproducing horn. Inverting the function of the recording horn, the reproducing horn picked up the faint sound vibrations given off by the reproducing diaphragm and effectively amplified those vibrations so that the resulting volume was sufficient for a number of people to listen together. The flowery horn of the phonograph soon became its most recognizable feature, until a new concealed-horn style of cabinet, introduced in 1906 as the Victor "Victrola," became standard.[22]

In 1907, *Littel's Living Age* described a collector who endeavored "to possess perfect specimens of the recording art. To this man the class of record is immaterial, his aim being only records which for clearness, volume, and quality of tone are absolutely faultless."[23] To this man and others like him, consuming sound quality was more compelling than listening to music. He derived pleasure from knowing that he had obtained the clearest and best-sounding reproduction possible, and his consummate taste enabled him to avoid the noises that characterized the inferior records that he had rejected. Competition among phonograph manufacturers was intense, and advertising campaigns encouraged all consumers to engage in such critical listening to determine which brand of phonograph offered the best sound.

The Edison Company preferred to compare its sound, not to that of competing machines, but rather to the sound of live music itself. From 1915 to 1926, the company sponsored Tone Tests, recitals in which phonographic "re-creations" of musicians, as reproduced by the Edison Diamond Disc Phonograph, were compared directly to live performances by those same musicians. In auditoriums and concert halls across the nation, curious crowds gathered to engage in a very public kind of critical listening. (See figure 6.4.) Opinions may have

varied as to whether or not the Diamond Disc re-creation was truly indistinguishable from the original, but more important, Tone Test audiences universally accepted the premise of comparison. The act of listening to reproductions was implicitly accepted as culturally equivalent to the act of listening to live performers.[24] The establishment of this equivalence was no small accomplishment; for years, the reproduced melodies of the phonograph had been disparaged as "canned music," mechanically preserved products that had more in common with a tin of sardines than with live music.[25] Tone Tests demonstrated, and perhaps helped bring about, a new willingness to accept these reproductions as an authentic aspect of musical culture. The tests also emphasized the importance of critical listening; an inattentive auditor who was not committed to careful, evaluative listening would not be able to distinguish, then obtain, the best possible sound. As countless phonograph ads made clear, such persons were bound to suffer—musically and socially—for their neglect.[26]

Tone Testing reached its peak of popularity around 1920, when over two thousand recitals were presented across the nation, including one at Carnegie Hall in New York. Subsequently, the number of events, as well as the attention paid to them, declined, and in 1926 the campaign was discontinued. By then,



6.4
Operatic soprano Marie Rappold performing a Tone Test Recital with the Edison Diamond Disc Phonograph at Carnegie Music Hall, Pittsburgh, 1919. The audience was challenged by the Edison Company to distinguish Rappold's live voice from its reproduction by the Diamond Disc. United States Department of the Interior, National Park Service, Edison National Historic Site.

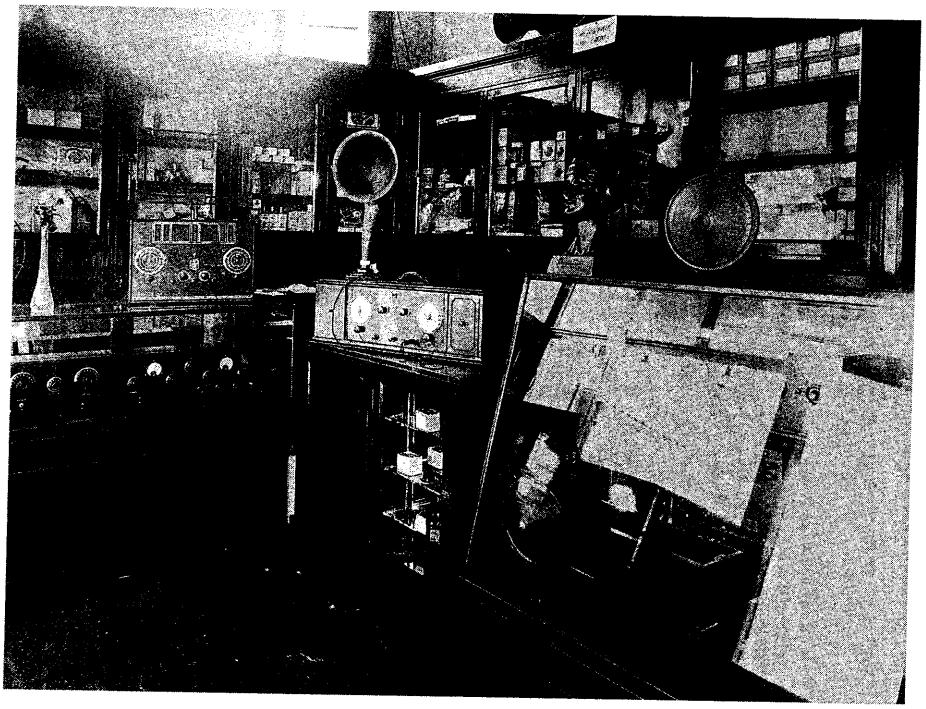
the novelty had worn off. More significantly, consumers were now far more interested in listening to the electrically generated sound of radio.

By 1925, radio receivers were no longer complicated contraptions whereby solitary auditors listened through headsets to intermittently broadcast signals. A rapidly growing industry now mass-produced products that any consumer—even the most technologically uninformed—could purchase, take home, and enjoy. A handsome cabinet concealed the tubes, wires, and other technological trappings. Tuning was still a skill that had to be acquired, but innovations in vacuum-tube technology and circuitry made this task easier and additionally improved the quality of the sound signals received.[27]

These improved receivers were accompanied by new sources of transmission. As commercial radio stations were established, beginning with Pittsburgh's KDKA in 1920, regularly programmed entertainment was broadcast to listeners across the nation. The first programmers simply played phonograph records into telephonic transmitters, but soon live musicians were being brought into the studio to perform into high-quality carbon and condenser microphones. The equipment was also taken out of the studio and set up in hotel ballrooms and nightclubs to broadcast the performances of jazz bands and dance orchestras. The result was that listeners at home heard a reproduced but "live" signal that offered a currency and connectedness to other listeners that even the most up-to-date phonograph record was perceived to lack.

Radio listeners were not only acoustically connected to distant companions simultaneously enjoying the same program, they were now also able to share that program with others in the immediacy of their own home. The old headsets were replaced by electroacoustic loudspeakers that projected the sound out into the room, enabling an entire family to listen together.[28] The earliest type of loudspeaker appeared around 1921 and consisted of a small electromagnetic receiver, like that found in a telephone earpiece, attached to a goosenecked horn. This model was soon accompanied by the "cone-type" loudspeaker, an electromagnetically driven paper diaphragm that was capable of filling a room with sound without the assistance of any horn.[29] (See figure 6.5.) Although the new loudspeakers now projected the sound out into the space of a living room or parlor, listeners preferred to sit close to their speakers, in order to receive as much of the direct sound output as possible. In doing so, they minimized the effect of the architectural locale upon their listening experience.

Loudspeakers did not simply amplify reproduced sound; they also added their own characteristic to the reproduction, and people generally enjoyed this



6.5
Radio shop in Peekskill, N.Y., c. 1925. Horn and diaphragm models of radio loudspeakers, as well as headsets, were sold here. The gooseneck horn sits on top of the receiver on the counter at the center of the image. A moving diaphragm, or cone, speaker is visible on top of the glass case to the right, with another inside the case on the bottom shelf. A headset is displayed on the fashionably modern mannequin head. George H. Clark Collection, Archives Center, National Museum of American History, Smithsonian Institution, SI negative #92-16437.

new kind of sound. The phonograph industry was inundated by a "flood of radio-generated public demand for more bass, more volume,"[30] and it responded by applying electroacoustic technologies to its own products. The techniques of electrical recording and reproduction developed at Bell Laboratories in 1925 were licensed by the Victor, Columbia, and Brunswick phonograph companies, and microphones replaced the recording horn in the studio. In the home, an electromagnetic pick-up replaced the reproducing diaphragm, a loudspeaker took the place of the horn, and the phonograph now offered the same "smooth, uninterrupted flow of sound" that radio listeners had come to love.[31] A 1927 advertisement for the Orthophonic Victrola described the new sound as "Vivid! Lifelike! As radically different as the modern motor-car in comparison to the 'horseless carriage.' And the new Orthophonic Victor Records, recorded by microphone, have a *character of tone* that is pleasing beyond description. Rich. Round. Mellow."[32] Edison had earlier boasted that his Diamond Disc phonograph had no tone of its own to distort the sound of the music recorded on its records.[33] With the new electrical phonographs, the characteristic qualities of electroacoustic reproduction became a desired feature, a commodity to be experienced and enjoyed.

Even as they transformed the habits and goals of domestic listening, loudspeakers were increasingly employed at sites for public listening. On 27 August 1928, for example, when Leon Theremin and his students performed before 12,000 people at Lewisohn Stadium in New York, the Theremin-Voxes on which they performed were equipped with "massive" loudspeakers. While music critics were wary of the potential of these new instruments for "practically unlimited volume," the *New York Times* indicated that the audience responded enthusiastically to the "loud full tones with a radio sound similar to a movie theatre vitaphone."[34] By 1928, stadium audiences were accustomed to hearing "radio sound" emitted from loudspeakers, as the use of public address systems for large gatherings of all sorts was now well established. And, as the *Times* acknowledged, movie audiences were also now encountering the sound of loudspeakers as Vitaphone, a new sound motion picture system, was transforming the movie-going experience.

Public address, or P.A., systems and Vitaphone sound movies were developed by scientists and engineers at AT&T as part of a strategy to expand the corporation's product line beyond telephony to encompass as many new electroacoustical sound products as possible. P.A. systems employed the same vacuum-tube amplifier that AT&T researchers had devised for use in radio and long-distance telephone transmission. Military applications of P.A. systems were explored during the First World War, and civilian uses for the technology were promoted soon after the war's end. Newsworthy events, including Warren Harding's presidential inauguration, were captured by microphonic receivers at their source, transmitted electrically over long-distance telephone lines, and then broadcast via loudspeakers to large crowds gathered at public sites in distant cities. The systems found numerous other more local applications and, by 1922, Western Electric was selling and installing P.A. systems anywhere that sound amplification was desired, including sports stadiums and ball parks, racetracks, convention halls, hotels, department stores, and large churches.[35]

Theater directors also found the systems useful. In 1922, Roxy Rothafel used a Western Electric P.A. system to direct rehearsals of his famous musical reviews.[36] Three years later, the now-improved system sounded good enough for the director to consider employing it during the show itself. With customary hyperbole Roxy proclaimed, "Acoustics no longer present a problem, since the amplification system, with which we are now experimenting, will carry the voice and will send it perfectly almost any distance within reason, and certainly

a distance greater than could be found in any theater."[37] Hyperbole soon became reality, and by 1929 Roxy was using the system to manipulate the balance between the string sections of his orchestra during the performance, as well as to enhance reception by the audience throughout the vast auditorium of the Roxy Theatre.[38] In 1932, Roxy's shows in the even larger Radio City Music Hall depended on a similar kind of sound system to broadcast their sounds to the huge audience assembled in the hall.

P.A. systems were also used by motion picture directors to instruct large crowds of extras during the filming of silent films. Previously, directors had shouted into enormous megaphones or created elaborate chains of command whereby instructions were transmitted, by gunshot, semaphore, or telegraph, to cadres of assistant directors scattered throughout the field of action. D.W. Griffith turned to signalmen from the United States Signal Corps to coordinate the large battle scenes in his 1915 epic, *The Birth of a Nation*. In 1923, Wallace Worsley became the first motion picture director to put the new Western Electric P.A. system to use as he shot *The Hunchback of Notre Dame*. Curiosity about the new system attracted other directors to the *Hunchback* shoot, and the visitors were impressed by what they heard there. Before long, the amplified commands of dictatorial directors were echoing across studio backlots all over Hollywood.[39] But the telephone company had far greater ambitions for transforming moviemaking, and its engineers now turned to the long-standing challenge of making the movies themselves talk.

Thomas Edison's earliest ideas for creating moving pictures had been stimulated by his invention of the phonograph, and he had intended from the very start to synchronize his images with recorded sounds.[40] Turning this idea into a working technology proved difficult, however. Only after years of work, with the considerable input of his assistant William K.L. Dickson, and with the abandonment of the idea of synchronized sound, was Edison able to achieve his goal of making pictures move.[41]

In April 1894, the world's first Kinetoscope Parlor opened. A former shoe store at 1155 Broadway in New York was now outfitted with ten of Edison's new motion picture machines. Each "peep show" Kinetoscope contained a twenty-second loop of film that customers viewed individually for a nickel a shot. Strongman Eugene Sandow flexed his muscles in one machine; in another, blacksmiths (Edison's own machinists) hammered a piece of iron and shared a bottle of beer. Other fare included a barber shaving a bearded customer, the contortions of Madame Bartholdi, and a pair of fighting roosters.

The novelty was a tremendous success, and exhibitors were soon placing the machines in bars, amusement parks, and arcades across the nation. Rival devices appeared, too, including the peep-show Mutoscope, in which the customer turned a crank to flip rapidly through a series of postcardlike photographs. The public developed a voracious appetite for moving images, and a new industry was born as producers photographed virtually anything that moved—from famous actors to risqué dancers to boxing cats—to meet the seemingly incessant demand.

Within a year, however, the novelty had worn off. Edison attempted to reinvigorate the business by returning to his idea of pairing the picture with sound. With the Kinetophone, a customer peered through the standard viewfinder and listened to the sound of an accompanying phonograph through a set of ear tubes. No synchronization was attempted, and the sound consisted of little more than background music. The films themselves were no different from the standard Kinetoscope fare, and the public not surprisingly failed to respond with enthusiasm to the new device.[42]

The nascent industry was rejuvenated not by sound, but by projection. In France, Louis and Auguste Lumière developed a means by which to project motion pictures onto a large screen, and by the end of 1895 they were offering regular screenings to paying customers in the basement of a Parisian café. The Edison Company's new Vitascope presented the first commercial projection of motion pictures in America in New York on 23 April 1896.[43] Moving images projected onto a large screen, and viewed in the company of others, left a far greater impression upon an audience than did the tiny, individually experienced peep-show images, and with projection, a new and permanent class of popular entertainment was established.

With projection, however, the challenge of providing synchronized sound became even more challenging. Now, there was not only the difficulty of maintaining synchronization between sound and image, but also the problem of providing sound loud enough for everyone in the theater to hear. Some enterprising impresarios avoided these problems by concealing behind the screen live actors who spoke and sang along with the characters projected onto it.[44] But numerous other inventors in Europe and America confronted the dual challenges of synchronization and amplification, and a variety of sound motion picture systems appeared in the first two decades of the century. None was a commercial success.

As early as 1902, Leon Gaumont's Chronophone presented films of French music hall performers who declaimed very loudly into a recording phonograph

that was located just out of camera range. Gaumont initially depended on two phonographs to provide sufficient sound in the theater, but in 1913 he turned instead to a phonograph whose output was magnified by a compressed-air amplifier. Early Chronophone demonstrations were generally well received, but the system was not economically viable for exhibitors. A trained operator was required to maintain synchronization between sound and image by constantly manipulating the speed of the projector to match the record. This labor was expensive and seldom up to the task, and the few exhibitors who tried the Chronophone soon dropped it from their programs.[45]

A similar system, the Cameraphone, was developed in America around 1906. The Cameraphone technique used phonographic recordings made in advance of the cinematography. During filming, the performers lip-synched their performance to match the record. Large-horned phonographs were employed in the theater to achieve maximum volume, but, as with the Chronophone, it was difficult and expensive to keep the sound in sync with the image, and the Cameraphone company went out of business in 1910.[46]

Edison himself tried one last time to marry his two inventions. A mechanically amplified phonograph playing large-diameter cylinders was tenuously linked to a projector via belts and pulleys; while initially impressive, Edison's system ultimately proved as vulnerable as others to the loss of synchronization. At the Kinetophone's debut in February 1913, the audience was "literally spellbound," but subsequent screenings were far less successful. Synchronization came and went, the amplifier amplified the surface noise of the record as well as the voices recorded upon it, and within a month *Variety* branded the Kinetophone "The Sensation That Failed."[47]

After this failure, the motion picture industry basically gave up on the idea of synchronized sound. If Edison himself couldn't make the movies talk, who could? Besides, the public clamored for silent films; why change an already successful product? The impetus to continue experiments now came, not from the industry itself, but from outsiders, electrical inventors and manufacturers who were not already benefitting from the success of silent films, and who had not been discouraged by previous attempts to add sound to them. These men realized that the vacuum-tube amplifiers and loudspeakers currently being used in long-distance telephony, radio, and public address could provide high-quality amplification of sound in a motion picture theater. All that was required was to find a means of maintaining synchronization between the image and the medium on which the sound was recorded.

Lee de Forest, whose audion tube was the basis for all forms of electroacoustic amplification, began experimenting around 1913 with a means to record sound onto photographic film. He developed a variant of his audion amplifier called the photion, which enabled him to generate an optical image of an electroacoustical signal. Inventor Theodore Case improved upon de Forest's design and devised a means by which to reverse the process, thereby re-creating the sound that had originally been recorded on film.[48]

Case and de Forest ultimately developed a system that provided synchronized and amplified sound, and the De Forest Phonofilm Corporation was formed in 1924 with Case as a partner. Several dozen theater owners were persuaded by de Forest to install his equipment and present the short sound films that Phonofilm produced. These films—typically musical numbers by vaudeville performers—met with mixed reviews, but cranky critics were soon the least of the inventors' worries. De Forest pursued creative financial strategies to generate operating income for Phonofilm, and he soon ran afoul of the United States Department of Justice. Case left the organization, taking with him the patents for his own contributions to the system, and de Forest's company went bankrupt in 1926.[49]

Simultaneous with the efforts of de Forest and Case, AT&T and General Electric—both of whom shared legal access to the technology of vacuum-tube amplification—also began to explore the development of sound pictures. GE researcher Charles Hoxie devised his own version of an optical sound recording system and euphoniously dubbed it the Pallophotophone. When the Radio Corporation of America was created in 1919 by merging the radio-related resources of GE and Westinghouse, the Pallophotophone was put to use to record music and speech for delayed radio broadcast. The company chose not to pursue its application to motion pictures.[50]

Unlike RCA, the telephone company was interested in moving into the movie business. Even as Western Electric's P.A. systems were finding their way onto Hollywood back lots, the company had begun to explore how best to make sound motion pictures. Experiments were made with both sound-on-film and sound-on-disc, but the Western Electric engineers chose to focus on discs, taking advantage of the recording skills they had developed when they electrified the phonograph. A means of maintaining synchronization between camera, phonograph, and projector was devised, and by 1924, salesmen were demonstrating the system to Hollywood's biggest players. But in 1924 no one was interested. Virtually all of the leaders in the industry had long since dismissed the viabil-

ity of sound pictures, and the phone company was not about to change their minds. While Paramount, Metro-Goldwyn-Mayer, and other first-tier studios all closed their ears to the new technology, a second-tier outfit run by four brothers named Warner chose instead to listen.

In 1924, Warner Brothers was a small but ambitious studio whose biggest asset was the canine action hero Rin Tin Tin. The studio had, however, recently initiated an aggressive campaign to become a dominant player in the production, distribution, and exhibition of films. As a part of this campaign, Warner Brothers purchased a radio station in Los Angeles, and Sam, the most technically minded of the brothers, supervised its operation as a medium of publicity for the studio. When shown the Western Electric sound film system, Sam liked what he heard and convinced his brothers that this was how the studio could make a name for itself. Sam proposed that they use recorded sound to replace the live music heard in their theaters. Short films of Broadway's best vaudevillians could replace the less-than-stellar local fare offered in provincial theaters, and recorded orchestral scores for feature films could similarly replace the variable quality of musical accompaniment that was rendered in each individual house. By offering a standardized and high-quality musical program, Warner Brothers could transform every Warner theater—no matter how small—into the equivalent of a "first-run" house and thus make their mark on the industry.

Warner Brothers and Western Electric joined forces in 1925 to form the Vitaphone Corporation, and on 6 August 1926, Vitaphone presented its first program at the Warner Theatre in New York. A brief address by Will Hays, president of the Motion Picture Producers and Distributors of America, opened the show. The image of the motion picture czar appeared on screen, and when his image audibly rapped its knuckles on the table in front of him, he immediately captured the audience's attention. Hays's talking image described how Vitaphone would inaugurate "a new era in music and motion pictures,"[51] and his address was followed by a series of "high-class" musical shorts. The New York Philharmonic performed Wagner's Overture to *Tannhäuser*, violinist Efrem Zimbalist and pianist Harold Bauer performed Beethoven's *Kreutzer* Sonata, and numerous other stars performed on screen and synchronized disc for the audience. Best received by far was tenor Giovanni Martinelli's dynamic rendition of "Vesti la giubba." The Vitaphone shorts were followed by the feature attraction, John Barrymore's *Don Juan*, a silent swashbuckler that was accompanied by a recorded, synchronized score of symphonic music with sound effects.[52]

Musical shorts followed by a sync-scored feature also made up the second Vitaphone program, and this time the performances of George Jessel and Al Jolson stole the show. Warner's competitors took note of the growing success of these films, but most producers remained convinced that Vitaphone was nothing more than a fad. Al Jolson's subsequent Vitaphone feature, *The Jazz Singer* (1927), would force them to reevaluate this opinion.

In *The Jazz Singer*, musical shorts by Jolson himself were effectively inserted into a nontalking, sync-scored melodramatic feature. But when Jolson's character briefly conversed with his mother before bursting into song in one such segment, the possibilities of truly talking films suddenly became obvious.[53] Over the next year, Warner Brothers released a series of "part-talking" films, and the percentage of talking footage gradually increased until, in October 1928, they could advertise *The Lights of New York* as the first "100% talking" feature film.

By 1928, Hollywood finally realized that this new sound technology would not fade away like its predecessors. RCA offered a sound-on-film system called Photophone to compete with Western Electric's sound-on-disc, and producer William Fox was turning out newsreels and feature films with synchronized sound provided by Theodore Case. Production of talking films increased dramatically during 1928 as studios frantically raced to build new soundstages, install new sound equipment, and learn how to operate it. The number of theaters wired for sound grew, too, as exhibitors were now eager to present the popular new films. By 1932, only 2 percent of America's theaters remained silent.[54]

Western Electric emphasized the connection between sound pictures and its older electroacoustic technologies by proclaiming the new technology "a product of the Telephone." RCA similarly designated its sound films as "Radio Pictures" to highlight their connection to its own electroacoustic products of the past.[55] But the transition to sound in the movies was strikingly abrupt, and it focused peoples' attention in a way that these earlier technologies had not. The celebratory publicity and intense competition surrounding the different systems led listeners to listen more closely than ever before. Audiences critically consumed these new products as they developed "the listening habit" as an important new element of their "modern life."[56]

The new habits of modern listeners were not simply a response to new technologies, however, and the sounds that they so carefully evaluated were not exclusively the output of electroacoustic devices. The same kind of sound to which they listened intently in the cinema was also encountered in places where no microphones, amplifiers, or loudspeakers could be found. Here, in modern

auditoriums and concert halls, that same clear, direct, and nonreverberant sound was strictly the result of architectural construction.

III The Modern Auditorium

Acousticians began to promote a new "ideal"[57] type of auditorium in the 1920s, and architects simultaneously made that ideal a reality. The new auditorium was low and wide, "spatulate"[58] or fan-shaped, with diverging side walls spreading out from a small stage area to form an increasingly wide seating area. The ceiling rose toward the rear to accommodate a balcony or two. The stage area was constructed of reflective materials, but the auditorium itself was highly absorbent. The acoustical result was that performers on stage effectively occupied the apex of a large horn. The sound that the audience received issued directly from the horn, or was perhaps once-reflected off the side walls. There was little opportunity for reverberation to develop, as the shape and material constitution of the new auditorium were designed "to blend and unify the music at its source and then transmit this music efficiently and uniformly throughout the extended seating area."[59] Efficient transmission—a primary goal in electroacoustical design—was equally valued in the realm of auditorium design.

Real examples of this ideal type include the Eastman Theatre in Rochester (Gordon & Kaelber, 1923); the Chicago Civic Opera Auditorium (Graham, Anderson, Probst & White, 1930); Severance Hall in Cleveland (Walter & Weeks, 1930); and the Kleinhans Music Hall in Buffalo (F. J. & W. A. Kidd with Eliel Saarinen, 1940). Numerous college and innumerable high school auditoriums also followed the trend. Describing the Kleinhans Music Hall in 1962, Leo Beranek wrote, "Listening to music there is rather like listening to a very fine FM-stereophonic reproducing system in a carpeted living room."[60] Historian Michael Forsyth has developed Beranek's characterization, identifying auditoriums built in America after 1925 as "Hi-Fi Concert Halls." Their sound, according to Forsyth, is sharp and lucid, much like a "'front-row' close-to-microphone recording."[61]

But the modern auditorium was more than a conscious or unconscious attempt to simulate architecturally the sound of electrically reproduced music. While the popularity of this type of auditorium was certainly reinforced by the similarity of its sound to that of the new electroacoustic technologies, its origins preceded the diffusion of those technologies. The historical development of this auditorium was the result of other factors, including the widespread use of