

## CONTENTS

*Acknowledgments* xi

*Abbreviations* xiii

Introduction	1
1 Weimar Radio: The Great Experiment	20
2 High Infidelity	40
3 Analyzing Distortions and Creating Fidelity	65
4 The RVS: Radio Experiments	97
5 The Original Trautonium	121
6 The Nazis and the Trautonium	148
7 The Trautonium after the War	181
8 Sala & Trautwein vs. the Cologne Studio for Electronic Music	211
9 Epilogue	226

*Notes* 235

*Bibliography* 297

*Index* 325

# Introduction

ON JUNE 20, those attending the Neue Musik (New Music) Berlin 1930 festival hosted by the Berlin Academy of Music listened to the debut of a new electric musical instrument: the trautionium.<sup>1</sup> The trautionium was named after its inventor, electrical engineer and physicist Friedrich Adolf Trautwein, who was assisted by Oskar Sala, a student of the renowned avant-garde composer Paul Hindemith at the academy. The performance featured a trio of trautioniums played by Sala, Hindemith, and Rudolf Schmidt. The reviews were mixed. Some felt the instrument was a laboratory joke, while others thought it was astonishing—the sensation of the festival—and that the concert marked the start of a new age of electroacoustic instruments. The numerous responses to the trautionium throughout its lifetime map nicely onto the myriad views concerning modernity. Those who embraced the instrument's so-called futuristic sounds saw it as reflecting a brave, new world, while others who did not share the optimism of such a future sharply criticized the instrument and insisted it neither was, nor ever would be, the music of the future. This book tells the story of that instrument.

The trautionium has enjoyed a lifespan of nearly a century, although its popularity has considerably waned.<sup>2</sup> It has gone through a number of instantiations, including the *Volkstrautionium* (people's trautionium), *Rundfunktrautionium* (radio trautionium), *Konzerttrautionium* (concert trautionium), and *Mixturtrautionium* (mixture trautionium). The instrument has been featured in a variety of entertainment genres, including classical music; *Gebrauchsmusik* (light music intended for amateurs); *Rundfunkmusik* (radio music, or music specifically composed for the radio); theater music; and sound effects for films and commercials. It has appeared in ballets, radio dramas, and operas, including several of Richard Wagner's—and at Bayreuth, no less. A number of leading composers—Paul Hindemith, Werner Egk, Paul Dessau, and Carl Orff—either wrote pieces for the instrument or used it as a substitute for other instruments. Renowned film director Fritz Lang used the trautionium in *The Indian Tomb*, which he directed in 1959. The trautionium's finest hour came in 1963, when



FIGURE 0.1. The first three musicians on the trautonium who performed at the Neue Musik Berlin 1930 festival hosted by the Berlin Academy of Music, June 20. Friedrich Trautwein is standing, Oskar Sala is seated on the left, Rudolf Schmidt in the middle, and Paul Hindemith on the right. *Source: Kestenber, Kunst und Technik, facing 112.*

Alfred Hitchcock had Sala play the instrument to produce the sounds of birds screeching and flapping their wings in his classic horror film *The Birds*. I like to say that the trautonium is the most famous instrument you have never heard of but that you have most likely heard.

In the first part of the book, I trace the confluence of a number of scientific, technological, political, and musical communities that existed during the 1920s and '30s and that resulted in the invention of the instrument. One such community is centered around early German radio, whose origins date back to the first public broadcast on October 29, 1923, in Berlin. The same equipment, skills, and practices used in radio were also employed in building the trautonium; indeed, the origin of the trautonium is imbricated with the early history of radio. While I agree with scholar Paul Théberge that the digital age witnessed the destruction of the boundary between media and instruments, I argue that that dismantling was already occurring in early-twentieth-century Germany.<sup>3</sup>

The second community that was necessary for the trautionium's invention comprised physicists and electrical engineers working on electroacoustics. This newly formed community—as leading German acoustician and physicist Erwin Meyer insisted—was created to solve the problems then faced by fledgling radio. Early German radio broadcasts were plagued by acoustical distortions that hampered the broadcast, making it difficult for even the most discerning musical ears to differentiate between instruments or voices. Physicists and electrical engineers, with the assistance of physiologists and phoneticians, were charged with fixing these distortions, particularly the ones that affected frequencies at the upper and lower ends of the radio station's frequency range, or bandwidth. The engineers and physicists of the Weimar Republic transformed radio into an instrument for relaying music and the human voice. This would become important for propaganda purposes after the Nazis' rise to power in January 1933.

The third intellectual community that contributed to the invention of the trautionium was musicians, particularly those experimenting in the relatively new genre of electric music. Numerous composers of the 1920s and '30s—including Hindemith, Edgard Varèse, Olivier Messiaen, Joseph Schillinger, and Carlos Chávez, to name just a few—were fascinated by these new instruments. Some musicians, such as Max Butting, Kurt Weill, Ernst Toch, and Hindemith, composed works that were specifically suited for the new medium of radio. A number of musicians were also engineers. For example, electrical engineer and organist Jörg Mager, author of *Eine neue Epoche der Musik durch Radio* (*A New Epoch of Music by means of Radio*), invented the spherophone in 1926.<sup>4</sup> Most famously, around 1920, Russian-Soviet electrical engineer and cellist Lev Sergeyevich Termen—better known in the West as Leon Theremin—invented the theremin, of which he conceived while repairing his radio. The theremin was very popular in Germany.

The site where these various communities—electroacoustics, radio research, and electric music—came together was also the laboratory where the trautionium was invented: the Funkversuchsstelle, which opened on May 3, 1928, in the attic of the Berlin Academy of Music. Later, the laboratory would be known as the Rundfunkversuchsstelle (the Radio Experimental Laboratory, or the RVS). Funded predominantly by the Prussian Ministry of Culture and the Reich's Broadcasting Corporation (the Reichs-Rundfunk-Gesellschaft), the RVS hosted immensely fruitful collaborations between natural scientists, radio engineers, and musicians who would go on to improve radio broadcast fidelity, develop *Rundfunkmusik*, teach the use of radio equipment to music students, and eventually invent an electric musical instrument. The RVS was the crucible where the skills, theories, and practices of these scholars were forged.

Given my own passions and abilities, I shall approach this book as a historian of science and technology, albeit one with musical training and an interest in musicology. I have spent much time (perhaps too much) thinking about German history, specifically the various Germanies of the past century and their corresponding (and often antithetical) political views of modernity. Those three related areas of interest—history of science and technology; musicology; and the histories of the Weimar Republic, the Third Reich, and the Federal Republic of Germany—provide the foundation of this book.

What are this book's intended contributions? For natural scientists, engineers, and historians of science and technology, this study offers the history of the physics and electrical engineering upon which radio was predicated. It details the role of those disciplines in inventing a cadre of electric musical instruments after World War I. This is also a story about a scientific instrument, namely the harmonic analyzer, the history of which was hitherto largely unknown despite its importance to the history of electroacoustics and radio. By following the development of late-nineteenth- and early-twentieth-century disciplines, such as applied physics, physiology, phonetics, psychology, radio and electrical engineering, and electroacoustics, we begin to see the various ways in which scholars in those fields defined and understood important musical and scientific phenomena such as tone color (also known by its French term, *timbre*), fidelity, and the formation of speech sounds.

While much more famous as a musical instrument, the *trautonium* became a scientific instrument used to adjudicate between Hermann von Helmholtz's theory of resonance and Ludimar Hermann's subsequent theory of impulse (or shock) excitation to explain the creation of vowel sounds and the development of a musical instrument's tone color. Trautwein was convinced that the *trautonium* was the electrical counterpart to the human voice organs and certainly saw his instrument as settling the debate on the side of L. Hermann. Finally, the book details the status of natural scientists and engineers in the various Germanies. Many famously were blamed for Germany's defeat in World War I, felt alienated throughout the Weimar Republic, tried their best to ingratiate themselves with governmental officials by actively supporting the Nazis, and attempted once again to regain acceptance after the defeat of the Nazis, despite their active roles in World War II.

Since radio provided challenging intellectual and practical problems beyond the limited horizons of traditional physics and electrical engineering, it is important that I address the technical aspects of physics and electrical engineering. Omitting the technical knowledge would render the story woefully incomplete. I ask for the reader's patience as I guide them through the denser material. We need to appreciate and comprehend the labor and skill (both intellectual and manual) that these scholars brought to the problem. Two works in particular

are relevant here: Wittje's important work on the history of electroacoustics and Yeang's outstanding tome detailing the technical history of the transformation of noise from an annoyance that electrical engineers attempted to ameliorate in electric sound reproduction to a subject relevant to understanding statistical detection, prediction, and the transmission of information.<sup>5</sup>

I hope the book will also appeal to musicologists. The trautionium was the quintessential modernist musical instrument, producing a new type of music that wished to distance itself both from classical compositions as well as those of Arnold Schoenberg, Alban Berg, and Anton Webern. This work also provides us with a better understanding of early radio and the music broadcast by important station managers such as Hans Flesch of Frankfurt, and later Berlin, by shedding light on the early years of Rundfunkmusik and its composers. It also contributes to the history of tone color during the 1920s and '30s, a period that witnessed an important metamorphosis in its meaning. By telling a hitherto unknown story of electric music and its relationship to electroacoustic and electronic music, musicologists can also begin to see the historically contingent processes of negotiation that defined those terms. The trautionium illuminates the relatively unknown debates between Trautwein and Sala on the one hand, and the pioneers of the Cologne Studio for Electronic Music—particularly Werner Meyer Eppler—on the other, as detailed in their correspondence. Their letters raise interesting questions about the definition of electronic music: Which aesthetic should be included and which should be excluded? What is the role of the composer in relation to the performer? Is there such a thing as an “authentic composition”?

Another relevant aspect of this book to musicologists interested in the twentieth century is the attempt to situate the trautionium within the *longue durée* of proto-synthesizers, as it shared a number of important features with them, including the synthesis of music and vowel sounds as well as the ability to imitate a large range of timbres and sounds. While many scholars realize that electric music predates World War II, we hear relatively little about instruments that shared some of the attributes of the synthesizers of the 1950s and '60s. RCA's Mark II (designed by Harry Olson and Herbert Belar), Max Mathews's work at Bell Labs on digital-computer music, and the Moog synthesizer were all postwar inventions.<sup>6</sup> When Mathews spoke on the history of synthesizers in 1985, he insisted that their origins were in the early 1950s with the work of Vladimir Ussachevsky and Otto Luening in New York City, Pierre Schaeffer in Paris, and Karlheinz Stockhausen in Cologne.<sup>7</sup> Oskar Sala wished to differentiate between his mixture trautionium and synthesizers for both entrepreneurial reasons and reasons of musical performance.<sup>8</sup> Unlike more modern synthesizers, the mixture trautionium did not possess sound envelopes or voltage-controlled filters or amplifiers. The functions of those devices were

achieved by manually controlled circuits. As we shall see, Sala wished to produce many of the effects created by synthesizers himself.<sup>9</sup> In his view, the machine should never completely replace the human.

Finally, for German historians and those interested in German studies, this book discusses the interest of leading German intellectuals of the 1920s and '30s in German radio in general and the RVS in particular, including Bertolt Brecht, Kurt Weill, Walter Benjamin, Alfred Döblin, and Theodor Adorno. The trautionium's history during the Third Reich was an intriguing one. While one might think that the Nazis would consider electric music degenerate, the opposite was true. The trautionium could serve their purposes in creating an aesthetic of "steely Romanticism," contribute to *Hausmusik* for the *Volk*, and provide entertainment for mass gatherings. It can therefore shed light on the complicated relationships the Nazis had with music and technology. Claiming that they opposed everything "modern" is simply fallacious. This work also offers an account of the trautionium's contribution to industry and cultural films as well as television and cinema commercials—and music culture in general—in the Federal Republic of Germany.

The instrument is quite unique, even among the electric musical instruments of the period. Its sounds were produced by a glow-discharge (neon) tube and later thyatrons, rather than using frequency beats as was the case with the theremin and ondes Martenot, or tuned tube oscillators as was the case with the Coupleux-Givelet organ and the Hammond Novachord. The laboratory where the instrument was invented, the RVS, was also unique. Due to the lab being housed in a musical academy as opposed to an engineering company, the majority of its work was dedicated to music. The RVS was, in a sense, a mirror image of Bell Telephone Laboratories: engineers and scientists in this US laboratory focused their research on the transmission of speech, and music initially played a secondary role. The historian can use the RVS as a foil to the Bell Telephone Laboratories, which were created by AT&T and Western Electric. Finally, no other country possessed the caliber of such intellectuals in those numbers writing about early radio and its laboratories. All of these points begin to explain the distinctiveness of the trautionium and the context of its invention. While this book does not seek to support the German *Sonderweg*, it does describe a number of peculiar aspects of German music, science and engineering, and politics that go a long way to explain why the trautionium was an invention of the Weimar Republic.<sup>10</sup>

Musical aesthetics is one theme that runs through this work. Addressing the disciplines with which this book wishes to engage—history of science and technology, musicology, and German history—I investigate how scientists and engineers defined and measured musical aesthetics, how musicians defined and experienced those aesthetics, and how politicians shaped or quelled

them. One example of musical aesthetics is tone color, defined as the quality of a sound that is unique to the instrument or voice that created it. That is to say, it explains the difference in tone between a cello playing a note at 220 Hz with a particular volume, and a piano playing that note with the identical pitch and volume. *Timbre* ties together the trauttonium, electroacoustics, politics, and music. The instrument could imitate the tone colors of a number of traditional musical instruments as heard by the ears of skilled musicians and as seen by oscillograms it produced when compared with the oscillograms generated by those traditional instruments. *Timbre* also was relevant to the radio, since it was difficult to broadcast with sufficient fidelity: distortions in the broadcast's tone color were due in large part to the radio transmission and receiving equipment, namely microphones, loudspeakers, and amplifiers. A history of musical aesthetics of the 1920s and '30s is simultaneously a history of those radio parts; therefore, musical aesthetics were inextricably linked to electroacoustic theories, skills, and practices. Since radio created an important market for these devices, engineers and physicists busied themselves with rendering the requisite improvements, thereby improving broadcast, much to the appreciation of attentive audiences.

Emily Dolan has provided us with a wonderful account of *timbre*, from its origins with the works of Jean-Jacques Rousseau to its solidification in the nineteenth century.<sup>11</sup> She argues that Joseph Haydn's style of orchestration of the late eighteenth century must be understood through the emergence of the public's interest in various instruments' *timbres*. More recently, Dolan and Alex Rehding have coedited a collection of essays on *timbre*.<sup>12</sup> The volume illustrates how tone color has now become a key theme of research for historians (including historians of science and technology), musicologists, philosophers, science-and-technology-studies scholars, and sound-study scholars.

A history of tone color is also a history of fidelity, another example of musical aesthetics that ties the book together. A vast majority of physicists and engineers had initially defined fidelity of *timbre* as a static comparison of the oscillograms generated by harmonic analyzers depicting the relative amplitudes of the overtones of broadcast voices and instruments with those of the original sounds.<sup>13</sup> During this period, however, an ever-increasing number of physicists and engineers—including Trautwein—as well as physiologists and psychologists realized that *timbre* was not static and that it hung over the interval of playing a note: what we now call the sound envelope. The initial portion of playing a note (the attack) possesses different *timbres* than the decay, which in turn possesses different *timbres* from those of the release. Only by recapturing and consistently reproducing the entire process could one begin to speak of fidelity of tone color. In addition, engineers at Bell Telephone Laboratories began to show that tone color was also somewhat dependent on volume.



Finally, psychologists increasingly criticized what they claimed were wrong-headed attempts by many physicists and electrical engineers to understand timbre without acknowledging the role of human perception.

Jonathan Sterne's pathbreaking work, *The Audible Past*, has provided us with the definitive study on fidelity, arguing that the creation of music is just as constructed as its reproduction.<sup>14</sup> Emily Thompson's *The Soundscape of Modernity* offers us a compelling aural, cultural, and technological history of twentieth-century America.<sup>15</sup> She demonstrates how the Edison Company persuaded the American public that a reproduction in the form of a phonograph could be a worthy substitute for a live performance. Reproducing fidelitous sound was the goal of those who had stakes in radio's success. Musicians, natural scientists, and radio engineers all actively participated in rendering radio a legitimate medium.

Given the range of expertise and disciplines of those interested in sound fidelity, perhaps it should not come as a surprise that one should actually speak of fidelities, rather than fidelity, during this period. The various definitions, however, had one thing in common: they were based on the problems that plagued early radio broadcasts. For Adorno, a fidelitous reproduction was one in which the listener's experience of a radio broadcast of a Beethoven symphony mirrored their experience in a concert hall. Even by the early 1940s, he famously argued that such a reproduction was not possible. Another definition dealt with the listener's inability to differentiate between the upper pitches of the flute and violin and hear the lower notes of the double bass. Engineers, natural scientists, and musicians also spoke of how the volumes of various groups of instruments during a broadcast differed from the relative volumes in the performance hall. In addition, researchers began to realize that the human ear does not hear linearly, but logarithmically, meaning that we hear some portions of the audio spectrum better than others. For example, one needs to greatly intensify the energy supplied to a pitch sounding at 100 Hz in order to hear it at the same volume of a pitch at 1000 Hz. Finally, we sometimes hear a third tone, known as combination tone, when two pitches with different frequencies are sounding together. Some of these tones are a product of the human ear: they cannot be detected by a physical apparatus such as a harmonic analyzer. They are referred to as subjective tones. The subjective could never be fully removed from the "objectively" generated results of scientific instruments. Properties of the human ear and mind needed to be better understood. Interesting debates arose in laboratories when skilled musicians insisted that they heard something that their state-of-the-art equipment did not register.

Timbre reproduction was only one problem, albeit a crucial one, of several problems with broadcast fidelity. The definitions of fidelity as the relative intensities of the overtones of the original sound and those of its reproduction

were critical to many of my historical actors. In addition, this interest in timbre fidelity over the radio led directly to the invention of the trautionium and is therefore emphasized in this book.

Given the various aspects of fidelity, I shall stress when my actors are speaking, or when it is my voice you hear. Michel Chion makes a relevant and important point: if there is more than one historical definition of fidelity, it is impossible to argue that fidelity is something objectively improved by tinkering with microphones, loudspeakers, and amplifiers.<sup>16</sup> As a historian, I am more interested in how my historical actors defined fidelity as it related to the broadcast timbres, and whether they thought it could be objectively quantified, and if so how.

The term *Naturtreue* (or “faithful to nature”) was often used during the 1920s and ’30s by musicians, physiologists, physicists, and engineers to indicate how close the broadcast sound was to the original. The word also referred to artworks depicting natural scenes as well as physiological and anatomical representations. *Klangtreue* (or “faithful to sound”)—the word used most often today to refer to musical fidelity—was also used during the 1920s and ’30s, albeit far less than *Naturtreue*.<sup>17</sup> Of course, *Treue* was also used.<sup>18</sup> As we shall see, however, the sounds created by voices and musical instruments in the broadcast studio were just as contrived and orchestrated as the corresponding transmitted sounds.<sup>19</sup>

Another definition of fidelity addressed in the second portion of the book is one not based on sound reproduction, but on the faithfulness to a cause or belief. Such was the case with Sala’s opportunism and Trautwein’s dedication to fascism, as the trautionium was transformed during the Third Reich into an “instrument of wonder.” Of course, such fidelity needed to be effaced after the war, and Sala was much more successful than Trautwein in distancing himself from Nazism. Despite the trautionium’s ability to imitate the tone colors of numerous traditional instruments with an impressive degree of fidelity (according to my historical actors), because of its versatility, it was also simultaneously infidelitous, as it could shed its affiliation both with any particular tone color and the prevailing political ideology during which it was invented and improved. By considering the themes of tone color and fidelity from a number of disciplines, it becomes clear that the agreements and disagreements between various professions add to our understanding of the historically contingent notions of subjectivity, objectivity, and the roles of the human and machine in defining musical aesthetics.

Like the Moog synthesizer, the trautionium contributed to a plethora of aesthetic qualities, which change over time. The first one was the aesthetic of *Neue Sachlichkeit* (New Objectivity), which was one of machine-like precision, order, and experimentation. Neil Grosch has argued that *Neue*

Sachlichkeit was an attempt to fuse modern music with society. It included *Gebrauchsmusik*, which by design was aimed at popular audiences, an attempt to distance itself from “highbrow” virtuosic music, Rundfunkmusik, and *Zeitoper*, the latter being a Weimar Republic invention with socially and politically relevant themes. *Zeitoper* often employed modern technology with a view to reach a much larger audience than had previously been the case.<sup>20</sup> Two other aesthetic qualities of the trautionium addressed in the book are imitation and the creation of unique, futuristic sounds and timbres.<sup>21</sup> Should newly invented electric musical instruments imitate traditional acoustical ones with a view to replicate or even replace them, or should they generate their own unique sounds? The original trautionium could do both, as Trautwein and Sala insisted from the moment of its invention. (Sala, after initially assisting Trautwein, went on to construct later models of the instrument on his own.) These two critical properties—imitation and creativity—appealed to numerous diverse audiences over a span of over seven decades. In an interesting way, they reflected the complexities of Berlin, a city that simultaneously wished to embrace modernity and was horrified by it. Some Berliners applauded the futuristic sounds the instrument could create, while others saw it as an important contribution to traditional German music. During the early 1930s, imitation was lauded by the radio company Telefunken as a marketing ploy for the Volkstrautionium, a household version of the instrument, since it was important to German Hausmusik. Imitation was also a favored characteristic among certain Nazi circles, particularly when it involved house music for the Volk. The Nazi Party did, however, sponsor trautionium concerts that played arrangements of classical pieces with new, unique tone colors and new works specifically composed for the trautionium. In addition, a key aesthetic during the Third Reich was “steely Romanticism,” a phrase coined by the Reich Minister of Public Enlightenment and Propaganda, Joseph Goebbels. The trautionium, a Germanic invention after all, was seen as cultivating that particular aesthetic quality.

After the war, the trautionium was often described as generating a new, modern, even futuristic, aesthetic, as technology increasingly shaped artistic expression. The trautionium’s ability to do so was an important ingredient in an aesthetic that wished to distance itself from the horrors of the Third Reich. The novel sounds now emanating from the instrument were an attempt to extricate itself from its fascist past. Ironically and critically, the trautionium could contribute both to the fascist aesthetic of imitation and “steely Romanticism” as well as an aesthetic of novelty meant to completely undermine Nazi aesthetics. Such versatility (some might say instability), however, was simultaneously a disadvantage, since any instrument possessing many timbres lacks a unique timbre of its own. After the war, Sala’s gumption ensured the instrument’s success. By stressing that the instrument was not restricted to one type

of aesthetic, he reached out to his listeners to assist him in creating new niches. It was the perfect strategy in the land of the *Wirtschaftswunder*, or economic miracle, of West Germany during the 1950s and '60s.

While imitation and creativity are epistemologically contradictory, the proponents of both the trautionium and the new medium of radio often shifted between claims of naturalism based on imitation and fidelity, and the invention of new sounds and genres. They are, in essence, two sides of the same coin. As with other (later) electronic musical instruments, the trautionium's interface elements were a trade-off between the player in the moment of performing and the complexity of tone shaping. Similarly, there was a continued shuttling between attempting to render the radio broadcast as true as possible to the original performance (mimesis) and arguing for a new type of music composed for the radio (invention).<sup>22</sup> Engineers and listeners were constantly on the lookout for proxies of truth-to-nature or imitation.<sup>23</sup> At the same time, the trautionium and the radio were meant to provide new and unique forms of experience for their performers and audience. One thinks of the electric guitar. Invented during the early 1930s, it initially was meant to increase the volume produced by acoustical guitars rather than offer a new type of sound. Jazz guitar performers used electric guitars to play typical guitar solos in large bands; extra volume was therefore necessary. As time went on, the electric guitar became an instrument that could create new timbres and sounds and contributed to numerous musical genres.

In addition to musical aesthetics, the politics of the various German nation-states and their numerous views on modernity are also themes that run throughout the book. As we have seen, politics is intricately and inextricably linked to musical aesthetics. The nation-state also shaped the research and roles of engineers and scientists in society. State politics played a role from the start of my story, as radio came under the purview of the Reich's Ministry of the Post Office. In addition, the RVS was predominantly state funded.

The year 1923, which witnessed the birth of German public radio, was a particularly tumultuous one for Germans. The terms of the Treaty of Versailles ending World War I were devastating. Political turmoil was a common occurrence throughout the Reich. Deadly skirmishes between the Communists and Nazis, which had formed as a political party in 1920, became a daily routine in cities such as Berlin. In January, French and Belgian troops occupied the Ruhr region of western Germany in response to Germany's refusal to pay war reparations. In August, German Chancellor Gustav Stresemann's first Cabinet was sworn in, which was followed closely by the swearing in of his second Cabinet about seven weeks later. In October a separatist government formed in the Rhineland Palatinate. In addition, both communists and fascists attempted to overthrow the Republic in different states. On November 23, Stresemann

resigned, having only served for just over a hundred days. Political chaos spelt economic doom: on November 15, the value of a German paper mark plummeted to approximately 1 trillion Marks per US dollar. Pictures of Germans carrying wheelbarrows containing suitcases full of Reichsmarks to purchase food at a local market became iconic.

Weimar German radio was dedicated to being impartial (*Überparteilichkeit*, or literally being “above partisanship”) and was also committed to underscoring the various dialects and cultures found throughout the Reich. No one language (such as *Hochdeutsch*), nor one culture among the German Volk was considered to stand above the rest. A “centralized decentralization,” as it was referred to, was the necessary model for Weimar radio’s success. Shortly before the rise of fascism, however, that had changed. German radio began to take political sides and infamously was used as an instrument of propaganda by Goebbels from 1933 until the end of the war. Under the Nazis, it was meant to unify the German Volk by stressing Hochdeutsch and various cultural characteristics shared by all Germans. The *Volksempfänger*, or radio receiver, was often referred to in the vernacular as “Goebbelsschnauze,” or “Goebbels’s snout,” and was now cheap enough for the workers to afford.

Just because the pioneers of early Weimar radio wished it to be impartial, it would a mistake to see it as being free from politics. As a result of the explosion of radio’s popularity throughout Europe and the United States in the late 1920s, various governments needed to impose restrictions on bandwidths to avoid unwanted interference due to the increase in the number of stations. These restrictions resulted in the cutoff of the overtones of high pitches and begin to explain why—in addition to the inefficiencies of the components of the transmitter and receiver—the soprano’s voice did not come across as well in broadcasts as it did in live performances. Political and economic decisions that sacrificed the soprano’s voice were made by men. Such a move was neither inevitable nor natural: there were alternatives.

The German nation-state also shaped engineering and scientific disciplines during the early twentieth century. The corresponding professions underwent rapid change from the late nineteenth century until well after World War II. By tracing the various discourses on modernity, particularly those espoused by leading engineers, one can begin to piece together their relationship with the German state and culture. By the second half of the nineteenth century, engineers were gaining in prestige, yet they still lagged behind those who were classically trained, the so-called *Bildungsbürgertum*, or the educated upper-middle class, whose education was based on the classical languages of Greek and Latin. The *Bildungsbürgertum* comprised the so-called free professions: high-ranking civil servants such as university professors, military officers, and church officials. A key to their education was German idealism as explicated

in the works of Immanuel Kant, Johann Gottlieb Fichte, Johann von Goethe, and Friedrich Schiller. In contrast, engineers were trained in the so-called illiberal disciplines, which were taught at technical universities (*technische Hochschulen*) across the land. Members of the Bildungsbürgertum often viewed engineers, even those with advanced degrees, with disdain.

Given the importance of engineers to the rapid industrialization of the burgeoning nation, Kaiser Wilhelm II gave technical universities in 1899 the ability to grant the degrees of *Diplomingenieur* and *Doktoringenieur*. Not surprisingly, engineers with *Doktoringenieur* degrees wished to be treated as equals to those who possessed the equivalent of a PhD in the humanities. They, too, sought the coveted status of *Kulturträger*.<sup>24</sup> Trautwein, who received his Dr. Ing. from the Technical University of Karlsruhe in 1921, certainly felt he earned such a status. Technology was for him, as well as many other well-educated engineers of the period, an integral part of German culture. With the disastrous end of World War I, German scientists and engineers alike suffered from a crisis of identity throughout the Weimar Republic and were often viewed as being culpable for Germany's defeat. As Adelheid Voskuhl has pointed out, while engineers desperately sought to be members of bourgeois culture (*Bürgerlichkeit*), being influenced by right-wing, antimodern ideologies, they often simultaneously loathed its liberal attitudes and values. Industrialization, seen by many as one of the defining characteristics of liberal modernity, according to Voskuhl, was in reality the cause of its death.<sup>25</sup> Like a disproportionately high percentage of engineers, Trautwein joined the Nazi Party in 1933. Many of the educated elite were sympathetic to the Nazis' vision of a new and glorious future. A staunch supporter of Nazi ideology, Trautwein assisted the Nazi Party with his acoustical expertise on amplification for large, outdoor rallies. After World War II, Trautwein attempted to reestablish the role of educated engineers as *Kulturträger* by waxing poetic on both the philosophy of technology and the importance of technology to culture.

The Nazis' Reichsmusikkammer (Reich Chamber of Music), the musical state agency under the control of the Ministry of Public Enlightenment and Propaganda, subsidized a later version of the trautionium, the concert trautionium, built by Sala, who toured with the instrument throughout the Third Reich, in occupied territories such as Holland, France, and Hungary, and in allied countries, such as Italy, with support both of the Reichsmusikkammer and the *Kraft-durch-Freude* (Strength-Through-Joy) programs.

Various nation-states certainly played a role in the type of musical aesthetic that was acceptable after the defeat of the Nazis. Sala and, to a lesser extent, Trautwein did their best to cultivate the interest of the Allied powers in the trautionium after the end of the war. Sala actively sought out patronage from the Radio in the American Sector (RIAS) in Berlin. He also attempted to interest

musicians in the Soviet sector of Berlin to build quartet trautioniums in the late 1940s. He subsequently found his niche in the capitalist industries of the Federal Republic of Germany.

This history of the trautionium is in part a story about the material culture of objects. As a material object of modernity, the trautionium challenges our preconceived notions about the isolation of various aspects of culture and science of the twentieth century. By offering a history of the trautionium, I hope to show how a musical instrument reconstituted the relationships between science, technology, politics, and musical aesthetics, thereby forcing us to rethink the notion of modernity.

The materiality of musical instruments, which owes much to Trevor Pinch and Frank Trocco's *Analogue Days*—a pioneering work on the history of the Moog synthesizer—has become the subject of numerous investigations over the past two decades.<sup>26</sup> Emily Dolan and John Tresch's important work on organology traces the intersecting and divergent histories of music and science by looking at scientific and musical instruments. Musical instruments render the inner emotions and thoughts of a composer accessible to the outside world, while scientific instruments transport the external world into the thoughts of the inner world of a scientist's mind.<sup>27</sup> Similarly, the musicologist Rebecca Wolf has worked on the materiality of musical instruments, while the musicologist Alexander Rehding has written on the relationship between instruments and music theory.<sup>28</sup> Furthermore, Thomas Patteson's work has given us wonderfully contextualized accounts of several electric musical instruments, including the trautionium, during the 1920s, '30s, and '40s.<sup>29</sup>

The past twenty years have also witnessed the publication of many works linking the history of music with the history of science and technology. I seek to continue that trend by merging a history of music, specifically aesthetics, with the history of science and technology.<sup>30</sup> For example, Peter Pesic has written the *longue durée* history of the relationship between music and science, *Music and the Making of Modern Science*, and his more recent work, *Sounding Bodies*, elucidates the influence of both music and sound on the structure and content of biomedical sciences.<sup>31</sup> Historian of science Alexandra Hui demonstrates how leading physicists, physiologists, and psychologists dedicated themselves to understanding sound from a psychophysical perspective. She deftly argues how musical aesthetics were inextricably linked with the natural sciences.<sup>32</sup> Hui, Julia Kursell, and my coedited volume, *Music, Sound, and the Laboratory from 1750 to 1980*, proffer an account of how laboratory sciences changed the notion of sound over two hundred years. Newly invented laboratory techniques of sound detection and representation and the use of electricity and computers to generate sounds fundamentally altered acoustics as well as musical practice. The musicologist Kursell has written a number of important essays on

nineteenth-century German science and music.<sup>33</sup> Theater and media studies scholar Viktoria Tkaczyk has recently shown how the elucidation of the function of the auditory cortex in the late nineteenth century influenced numerous academic disciplines in the natural sciences and humanities.<sup>34</sup>

While historians contributing to sound studies have argued for quite some time against separating aesthetics from science and technology, the theme is still unrepresented in the history of science and technology more broadly speaking. This work seeks to illustrate how one accounts for the mutual implications of aesthetics, science, and engineering. There have been a small number of important contributions on aesthetics and science provided by historians of science. Michael Dettelbach's influential essay is one of the first on this topic: he demonstrates how the Humboldtian aesthetic was based on precision measurement. I have offered examples along those lines with respect to physics and music. My *Harmonious Triads* explores how physicists such as Wilhelm Eduard Weber contributed to musical aesthetics in the nineteenth century. For example, Weber's work on compensated reed pipes, which were used to experimentally test the ratio of the increase in pressure and the increase in density of a sound wave, also led to the invention of organ pipes that could increase in volume without increasing in pitch. Organs now became expressive. Robert Brain's *The Pulse of Modernism* is an important study linking the origins of artistic modernism to physiological theories of perception forged in late-nineteenth-century French laboratories. "Physiological aesthetics" altered the way artists, poets, and musicians plied their craft and in so doing changed the notion of art itself. Deborah Coen interweaves a wonderful account of the relationship between science, politics, and aesthetic qualities in the visual arts and liberalism in nineteenth-century Vienna by tracing the history of the Erleben family in her *Vienna in the Age of Uncertainty*.<sup>35</sup> John Tresch's *The Romantic Machine* is a magisterial tome addressing how the sciences and the arts, rather than being antithetical, were critical for uniting a deeply fractured nineteenth-century French society. Finally, Norton Wise argues for the importance of the aesthetic sensibilities involved in drawing and the visual arts to Hermann von Helmholtz's early work on physiology.

The trautionium itself has attracted the attention of scholars lately. Two recent works are doctoral dissertations in musicology and media studies: Benedikt Brilmayer, "Das Trautionium: Prozesse des Technologietransfers im Musikinstrumentenbau," and Christina Dörfling, *Der Schwingkreis: Schaltungsgeschichten an den Rändern von Musik und Medien*.<sup>36</sup> In a third, Peter Donhauser adroitly details the complex technological developments of the various instantiations of the trautionium from its origin to the mixture trautionium some twenty-two years later.<sup>37</sup> There has been, however, very little written on the instrument in English.<sup>38</sup>



Much like Aldous Huxley's *Brave New World*, where the protagonist Bernhard Marx does not appear until after the initial chapters, the protagonist of my story, the trautionium, does not immediately appear in my work either. Switching the roles just for the analogy, just as Marx disappears in favor of John in Huxley's work, the radio succumbs to the trautionium. I feel the trautionium's late appearance is justified, since I need to trace the various traditions that formed the instrument's context to appreciate how the instrument came about.

Chapter 1 details how early German radio was considered to be an experiment by one of its pioneers, Hans Bredow. Radio would teach and entertain the German people at a time of economic devastation and extreme political uncertainty in the aftermath of World War I. Brecht stressed that radio needed to be experimental in order to render transparent the arcane processes occurring daily in the Reichstag. He hoped the RVS would improve radio broadcasts, as he saw the apparatus as critical to the education of the German people. Radio created a new musical genre (Rundfunkmusik) and a spoken genre (*Hörspiele*, or radio dramas), which were invented because of the medium's popularity. Furthermore, new musical forms featuring electric musical instruments, such as the trautionium, were broadcast over the radio.

Chapter 2 traces the history of fidelity by investigating the challenges that physicists and engineers faced trying to improve the broadcasting of tone colors. Violins were often mistaken for flutes or clarinets. During opera broadcasts, the soprano's voice came across as dull. Such infidelity gravely threatened the young medium's future; therefore, it is not a surprise that there was a certain urgency in the research conducted on linear and nonlinear distortions that plagued broadcasts, as discussed in chapter 3. Throughout the 1920s and '30s, radio engineers and physicists used harmonic analyzers to study the effects of the components of the transmitter and receiver on the relative amplitudes of a sound's overtones. This provided scientists and engineers with a metric of fidelity that in turn could be used to determine the imperfections of the equipment that needed to be remedied. Scientists and engineers conducted their experiments in laboratories of major German electrical engineering companies such as Siemens & Halske, Allgemeine Elektrizitäts-Gesellschaft (AEG), and Telefunken, collaborating with numerous governmental and university laboratories. Their major competitors were researchers at US companies, particularly Western Electric and American Telephone and Telegraph Company (AT&T), and Bell Telephone Laboratories (from 1925 onward), Radio Corporation of America (RCA), and General Electric (GE).

The RVS is the subject of chapter 4. Established in 1928, it was the site of experimentation of myriad issues for natural scientists, physiologists, phoneticians, engineers, and musicians. The RVS improved broadcast fidelity, invented a new instrument, and tested microphones, loudspeakers, and amplifiers. It

contributed to the genre of Rundfunkmusik, taught students how to work with microphones, and it also hosted the experiments of Hindemith and his fellow Neue Sachlichkeit composer Ernst Toch on how changing the speed of a recorded sound alters the sound's timbre. Arnold Schoenberg stopped by the RVS and encouraged Trautwein and Sala to increase the range of the trautionium to the range of the grand piano. The musicologist, psychologist, and physiologist Carl Stumpf visited the RVS and was amazed by the number of overtones the trautionium could produce.

As discussed in chapter 5, the trautionium was invented during the height of Neue Sachlichkeit. Hindemith, one of the movement's leaders, was the first and by far the most important musician who composed pieces for the instrument. It was a period when electric musical instruments filled the ether waves of radio and concert halls. Debates erupted about this new genre of music. Was it an example of mechanical music? If not, how was it different? Could the new instruments be of assistance to what many felt was the stagnating genre of musical composition by unleashing new tone colors? Did musicians welcome or spurn the role played by natural scientists and radio engineers in establishing a new musical aesthetic?

Although the vocoder, invented in 1938 by Homer Dudley at Bell Telephone Laboratories, was much better at synthesizing speech, the trautionium predates it in synthesizing vowel sounds. The trautionium was taken up in debates among physiologists and phoneticians about vowel production. Drawing upon the research of Stumpf, the physicist Dayton Clarence Miller, and the radio engineer Karl Willy Wagner of the 1910s and '20s, Trautwein argued that the vibrations generated by impulse (or shock) excitation that produced musical sounds were the electrical equivalent of the vibrations created by air traveling through the speech organs giving rise to the vowel sounds. The damped and decaying vibrations formed the formants, or the dominating overtones of a musical note or speech sound that determined its timbre. Such investigations were critical to radio broadcasting fidelity.

After initially focusing on the origins of German radio and the trautionium much like a convex lens, the second portion of the book behaves like a concave lens, radiating out to trace the various trajectories of the instrument. Both Trautwein and Sala realized shortly after the National Socialists' rise to power that they needed to convince the Nazis to support their work on the trautionium, as detailed in chapter 6. Iverson has written on the Nazi past of physicists and engineers working on electronic music after World War II, particularly Werner Meyer-Eppeler.<sup>39</sup> Trautwein was no exception. While Sala never joined the Nazi Party, he possessed business savvy and certainly benefited from the party's patronage. Goebbels thought that the trautionium could serve as a perfect instrument for Hausmusik and was delighted to hear about its potential

use in mass rallies. He was deeply impressed by the instrument after being granted a private demonstration and performance by Sala in April 1935. The trautionium could play traditional works of Paganini, Beethoven, Mozart, and Bach for violin, flute, cello, and organ. Here imitation was key. But more modern pieces by Harald Genzmer and Ferruccio Busoni—the Italian composer who influenced the Italian Futurists, many of whom were sympathetic to fascism and supporters of Benito Mussolini, were also featured. A number of critics, amazed by the range of tone colors that the instrument generated, labeled it a “Wunderinstrument.” Chapter 6 also tells the story about the role a particular engineer, namely Trautwein, played in supporting the Third Reich. In that respect, he was typical of many German engineers during the period.

After the war, Trautwein receded into the background, as discussed in chapter 7. He did, however, write a number of essays reflecting on the engineer’s role in German culture. Reminiscent of the attempts by natural scientists and engineers to redeem themselves before a skeptical public after the humiliating defeat of World War I, Trautwein wished to carve out a space for electrical engineers contributing to music with a hope of restoring his and his discipline’s reputation with the newly created state of the Federal Republic of Germany and its intellectuals. Sala, on the other hand, continued to experiment with the instrument. While he still used the trautionium to imitate more conventional instruments, he branched out into other genres, thereby enabling his instrument to unleash unique, futuristic, and uncanny timbres employed in radio dramas and theater pieces. The concert trautionium was often used by composers who wished to make a conscious break with the Nazis’ legacy, for example Brecht and Paul Dessau’s operas, *Die Verurteilung des Lukullus* (*The Condemnation of Lucullus*) and *Deutsches Miserere*. Sala’s final invention, the mixture trautionium of 1952, produced sound effects for operas, such as the Grail bells in Richard Wagner’s *Parsifal* and the hammering sounds of the goldsmith in *Das Rheingold*. While some critics praised the instrument’s versatility, others were troubled by the monstrous cacophony it produced. By the time he retired in the 1990s, Sala had played his mixture trautionium for over one hundred radio and television commercials and three hundred films, a number of which were commissioned by various chemical and Big Pharma companies in West Germany.

The music the trautionium played was not the only type of new music filling the airwaves in postwar Europe. Pierre Schaeffer and his *musique concrète* cohorts in Paris were creating new types of sounds by manipulating tape. Meyer-Eppler and his colleagues, Robert Beyer and Herbert Eimert, created the Studio for Electronic Music in Cologne. As discussed in chapter 8, Trautwein and Sala competed with these groups, particularly the Cologne Studio, to help preserve their contributions and legacy to postwar music. Sala in particular thought hard about the ways that tape recording increased the types of tone colors and

sounds that could be combined, as tape provided a new experimental system for the instrument. The competition was fierce, and the trauttonium featured prominently in the crucial debates, such as the role of the performer as interpreter of a composition, the importance of experimentation and improvisation with the instrument while playing, and the use of tape recording while performing. Would the future of music consist of instruments made of vacuum tubes and electric circuits, or (later) transistors? Would electronic music be successful in eliminating the human in music altogether?

This is a story about twentieth-century science and the social spaces where it occurred, the metropolises. By the late nineteenth century, science had been reorganized and had become slightly more egalitarian due to less social stratification. While women and people of color were still massively underrepresented, many more people were participating in science compared to earlier in the century. Much of that was due to the rise of the engineering disciplines as well as heavy industry, and World War I certainly accelerated the transformation. Metropolises such as Berlin provided a venue where a vast multitude of skills and expertise from newly created industries and disciplines, or previously existing ones that had had no contact with each other, began to combine in extremely fecund collaborations. Physicists and electrical engineers were now working with physiologists and musicians. We all know about “Big Science”; however, this particular story is about the relationships between science, technology, and music—their complexities as well as their interrelatedness—that generated explicit collaborations that enabled the creation of new aesthetic concepts and technical possibilities.

## INDEX

Note: Page numbers followed by an *f* refer to figures.

- Abendroth, Walter, 142  
*Abraxas* (Egk), 191  
acoustical distortions, German radio and, 3  
acoustical envelope. *See* sound envelope  
Adorno, Theodor W.; German radio and, 6, 8; infidelities and, 61–64  
advertising, 25  
aesthetics, 14, 33, 37–38, 50, 66, 98–99, 108, 122, 206, 209, 225–226, 231, 233; physiological aesthetics, 15; politics and, 11, 39; steely romanticism aesthetic, 10, 178; theme of, 6–7; of the trauttonium, 9–10; Trautwein and, 183–187  
album-oriented rock, 231  
Allgemeine Elektrizitäts-Gesellschaft (AEG), 23, 95, 112  
*Allgemeine Musikzeitung*, 161  
aluminum, 203  
*Alvorado—Aufbruch in Brasilien* (*Alvorado—Departure in Brazil*), 205  
Amar Quartet, 34  
Ambrosius, Hermann, 178  
American Telephone & Telegraph (AT&T), 6, 73, 89, 95  
amplifiers, 95, 106, 113–114  
*Analog Days* (Pinch and Trocco), 14  
*Anbruch*, 61  
Ankara Conservatory, 157  
Annual Musicians Conference of the General German Music Association, 164  
Armstrong, Edwin Howard, 231  
Arnold, Harold DeForest, 74, 89  
art, technology and, 184–187  
artificial intelligence (AI), 232–233  
atonality, 98  
*The Audible Past* (Sterne), 8  
“authentische Kompositionsweise” (authentic manner of composition), 216–221  
Backhaus, Hermann, 45, 125  
Baier-Post, Eva, 190  
Balanchine, George, 206  
ballets, 205–207  
Band, Lothar, 142, 174  
bandwidth: fidelity and, 3, 51–53; regulation of, 54–55; restrictions on, 12  
Battistini, Mattia, 49  
*Bayerische Funk-Echo*, 155  
Beatles, 232  
Beecroft, Norma, 224  
Beer Hall Putsch, 23  
Beethoven, Ludwig van, 20, 62–63  
*Die Begriffe “Wirtschaft und Technik” und ihre Bedeutung für die Ingenierausbildung* (*The Concepts “Economy and Technology” and Their Importance for Engineering Education*) (Schenk), 185  
*Beiträge zur Akustik und Musikwissenschaft* (*Contributions to Acoustics and Musicology*), 69  
Bekar, Herbert, 122  
Békésy, Georg von, 199  
Bekker, Paul, 37–38  
Belar, Herbert, 5  
Bell Telephone Laboratories, 6–7, 16–17, 40, 50, 54, 65, 71, 73–75, 78, 80, 92–93, 99, 120, 124, 182, 215  
Benjamin, Walter, 6, 30, 61, 62, 97  
Berg, Alban, 5  
*Der Bericht der Reichs-Rundfunk-Gesellschaft* (*The Report of the Reich’s Broadcasting Corporation* [RRG]), 151

- Berlin Academy of Music, 41; Funkversuchsstelle (RVS) (Radio Experimental Laboratory), 3; Nazi Party and, 155; Neue Musik (New Music) Berlin festival, 1
- Berlin Alexanderplatz* (Döblin), 61
- Berlin City Opera, 188
- Berlin Radio Choir, 49
- Berlin Radio Orchestra, 22, 49
- Berlin State Opera, 23, 49
- Berliner Zeitung*, 174
- Berten, Walter, 156
- Beyer, Robert, 211, 215, 223
- Bieberbach, Ludwig, 146
- Bild-und Klangakademie (Picture and Sound Academy), 181–182
- Bildungsbürger, 44
- Bildungsbürgertum: engineers and, 43; German idealism and, 12–13; patriotism of, 44
- The Birds* (Hitchcock), 2, 226–228
- Blatthaller, 92
- Blech, Leo, 191
- Blum, Carl Robert, 38
- Boeckmann, Kurt von, 36
- Boehm, Theobald, 73
- Böhm, Karl, 191
- Borgelt, Hans, 195
- Bori, Lucrezia, 54
- Borowicz, Hans Jörg, 228
- Borris, Siegfried, 103, 189–190
- bowed instruments, 82
- Brahms, Johannes, 59
- Brain, Robert, 15
- Brand, Max, 230
- brass instruments, 82, 195–196
- Braun, Alfred, 111, 152
- Braun tubes, 113
- Brave New World* (Huxley), 16
- Brecht, Bertolt: *Deutsches Miserere*, 194–195; German radio and, 6, 37; Hindemith and, 156; influence of, 201; *Neue Sachlichkeit* (New Objectivity) and, 38; *Rundfunkmusik* (radio music) and, 60; *Threepenny Opera*, 149–150; *Die Verurteilung des Lukullus* (*The Condemnation of Lukullus*), 192–194; works by, 97
- Bredow, Hans, 23, 26–27, 28, 30, 115, 150
- Brentano, Franz, 69
- Brilmayer, Benedikt, 15
- Bronsgeest, Cornelis, 49
- “Brüder zur Sonne zur Freiheit” (“Brothers to the Sun, to Freedom”) (Mager), 155
- Brussels Plan, 53
- Buchmann, Gerhard, 81
- Buddenbrooks* (Mann), 43
- Burgartz, Alfred, 172
- Buschkötter, Wilhelm, 51
- Busoni, Ferruccio, 98, 147, 162
- Butting, Max, 3; fidelity problems and, 45, 51; Funk-Stunde Berlin and, 36; *Neue Sachlichkeit* (New Objectivity) and, 39; *Rundfunkmusik* (radio music) and, 57–59, 60; RVS and, 103–104; Sala and, 190
- C. Lorenz, 24, 95
- Cage, John, 211
- Cahill, Thaddeus, 122
- Canby, Edward Tatnall, 206–207
- carbon microphones, 47, 50, 87–89, 88f. See also microphones
- Cassirer, Ernst, 178
- “La cathédrale engloutie” (“The Sunken Cathedral”) (Debussy), 164
- cathode-ray tubes, 113
- cello, 45–46
- Chávez, Carlos, 3, 161
- children, 31–32
- Chion, Michel, 9, 49
- chronometer (Synchronisationapparat), 38
- cinema, 97
- classic rock, 231
- Coen, Deborah, 15
- Cologne Studio for Electronic Music, 5, 212–214
- combination tone(s), 80, 87, 113
- Communists, threats to the Republic, 22–23
- composers, role of, 5, 212–220, 225
- composition, authenticity and, 216–221
- concert instrument. See Konzertinstrument
- concert trautionium. See Konzerttrautionium
- condenser microphones, 79, 88f, 89–90. See also microphones
- cone speakers, 95
- consonants, 54, 79, 101, 107, 139f, 140
- Constitutional Hall, 93
- Coupleux-Givelet organ, 6
- Cowell, Henry, 144
- Crandall, Irving Bardshar, 71, 73–74, 89
- creativity, quality of, 10–11

- crystal sets, 31–32  
culture, technology and, 44, 146  
Curtis, A. J., 75
- Darmstadt International Summer Course, 212  
Debussy, Claude, 38, 164  
*The Decline of the West* (Spengler), 184  
Delannoy, Marcel, 191  
Demian Quartet, 34  
democratic techniques, 42  
Dessau, Paul, 1; *Deutsches Miserere*, 194–195;  
    *Faust I*, 190–191; *Die Verurteilung des*  
    *Lukullus* (*The Condemnation of Lukullus*),  
    192–194  
Dessauer, Friedrich, 44, 184, 185  
Dessoir, Max, 146  
*Detektoren* (detectors), 31–32  
Dettelbach, Michael, 15  
Deutsch, Herbert, 230  
*Deutsche Allgemeine Zeitung*, 142, 157, 176  
*Deutsche Bühnenaussprache* (*Language of*  
    *German Theater*) (Siebs), 151  
*Der deutsche Rundfunk* (*German Radio*), 46,  
    123  
Deutsche Welle, 25  
*Deutscher Geist in der Technik* (*German*  
    *Spirit in Technology*) (Schroter), 185  
*Deutsches Miserere* (Brecht and Dessau),  
    194–195  
“Das Deutschlandlied,” opening concert for  
    the first German public radio broadcast  
    and, 22  
Deutschnationale Volkspartei (DNVP), 150  
dialects, 29–30  
Dietrich-Eckart Open-Air Theater, 165  
Dietz, Wilhelm, 112  
difference tones, 80  
digital age, Théberge on, 2  
disc recording, 103  
distortions: German radio and, 3, 42; linear  
    and non-linear, 16, 85–87, 93–95, 111, 113,  
    117–118, 216, 220  
Döblin, Alfred, 6, 61  
Dobrindt, Otto, 168  
*Doktor Faustus* (Mann), 153–154  
Dolan, Emily, 7, 14, 135  
Donhauser, Peter, 15  
Dörfling, Christina, 15  
Dradag (Wireless Service), 27–28  
Drahtloser Dienst (Wireless Service), 27–28  
*Dresdener Neueste Nachrichten*, 170  
Dudley, Homer W., 182, 215  
duralumin, 92  
Durniok, Manfred, 205  
“Durst” (Rutenborn), 196  
dynamophone, 122
- E. F. Huth Berlin, 115  
Ebert, Friedrich, 23  
Eckersley, P. P., 53  
Eckert, Gerhard, 152  
Edison Company, 8, 44–45  
Egk, Werner, 1, 189, 191, 202  
Eichhorn, Karl, 29  
Eidens, Josef, 200  
Eildienst, 24  
Eimert, Herbert, 182, 211–213, 215, 222–223,  
    224  
Einstein, Albert, 97  
Eisenmann, Alexander, 175  
Eisler, Hanns, 39  
electric guitar, 11  
electric music, 3; goals of, 119; Nazi Party  
    and, 149–150; popularity of, 121  
electrical engineers, community of, 3  
electroacoustics, 3–5, 7, 84, 110, 114, 119, 122,  
    182, 188; creation of, 41–42, 73  
electrochord, 123–124  
electrodynamic speakers, 95  
electronic ballets, 205–207  
electronic music, 207–208, 211–214, 221–222  
*Electronics* ballet, 206–207  
electrostatic speakers, 95  
*Elektrische Klangerzeugung: Elektronische*  
    *Musik und synthetische Sprache* (*Electrical*  
    *Production of Sound: Electronic Music and*  
    *Synthetic Language*) (Meyer-Eppler),  
    214–215  
*Elektrische Musik* (Lertes), 131  
*Elektrische Musik* (Trautwein), 119, 127  
“Elektronische Kompositionstechnik”  
    (“Electronic Technique of Composition”)  
    (Meyer-Eppler), 216–217  
Elektrotechnische Verein (Electro-Technical  
    Association), 78  
engineers and engineering: education of,  
    43; German economy and, 115; influence  
    on, 12–13; Nazi Party and, 165, 214; status  
    of, 43–44, 186  
Enkel, Fritz, 212, 223

- entertainment (*Unterhaltung*), German radio and, 27, 36
- Eppler, Werner Meyer, 5
- equipment: used by RVS, 108–109. *See also* amplifiers; loudspeakers; microphones
- European Radio-Electric Conference, 53
- Exhibition of Degenerate Music, 153
- Express Service for Official and Private Commercial News Limited (Eildienst für amtliche und private Handelsnachrichten G.m.b.H.), 24
- Der Fächer (The Subjects)*, 205
- “Der Fall Hindemith” (“The Hindemith Case”), 157
- Fanck, Arnold, 144
- “Fantasie-Demonstration für Mixturtrautonium” (Sala), 229
- fascism: engineers and, 150; Trautwein’s dedication to, 9
- Faust I*, 190–191
- Federal Radio Commission, 55
- Federal Republic of Germany, 4, 6, 11, 14, 18, 186, 209, 231
- Feigl, Georg, 146
- Felix der Kater im Zirkus (Felix the Cat at the Circus)*, 38
- Fernschreiber (teletype machine), 106
- Fichte, Johann Gottlieb, German idealism and, 13
- fidelity: aspects of, 8–9; challenges of, 40–43; defined, 7; improvements to, 77; RVS and, 108–110; understanding of, 4. *See also* infidelities
- films and the film industry: *Alvorado—Aufbruch in Brasilien (Alvorado—Departure in Brazil)*, 205; *The Birds* (Hitchcock), 2, 226–228; *Der Fächer (The Subjects)*, 205; *The Indian Tomb* (Lang), 1, 205; *Mit Farben begann es (It Began with Colors)*, 205; Mixturtrautonium and, 202–203; Movietone sound system and, 93; *Olympia* (Riefenstahl), 104; *Eine Reise zum Mond (A Journey to the Moon)*, 205; *Rosemary* (Thiele), 205; *Stahl—Thema mit Variationen (Steel: Variations on a Theme)* (Niebling), 205; Vitaphone sound system and, 93
- Finking, Ernst, 106
- Finking-Reyton, 113
- Fischer, Emil, 101
- Fischer, Erwin, 103
- Fischer, Wilhelm, 47
- Flesch, Hans: broadcasts by, 5; electric music and, 33; fidelity problems and, 46–48; Funk-Stunde Berlin and, 35–37; Oranienburg concentration camp and, 152; *Rundfunkmusik* (radio music) and, 60
- Fletcher, Harvey: human perception and, 124; research of, 54, 65, 68, 73–74, 95
- folding (portable) speakers, 112–113
- formalism, 193
- formants, 67–69, 76–77, 79, 84–85, 107–110, 113, 120, 122, 127, 130, 132–136, 139–140, 147, 159, 229
- Fourier analysis, 67, 71, 140, 199
- Fourier series, 67, 133, 135, 137f
- Fox Tönende Wochenschau* (Fox Resonating Newsreel), 144
- Frankfurter Zeitung*, 143
- frequencies. *See* bandwidth
- frequency modulation (FM) radio broadcasting, 231
- Friebe, Wolfgang, 178
- Friedrichkarl, 28
- Friesisch* (Friesian), 29
- Führer, Karl Christian, 25
- Fuldaer Zeitung*, 177
- Funk*, 85, 99, 142, 144
- Funk, Heinrich, 176
- Funk, Walther, 162
- Funk Bastler*, 144
- Funkschau*, 175
- Funkschule (Radio School), 164
- Funk-Stunde Berlin: broadcasting hours, 33; employees of, 152; experimentation and, 35–37; instruction (*Belehrung*) and, 34; microphones used by, 90, 91f; opening concert for the first German public radio broadcast and, 20; RVS and, 101
- Funkversuchsstelle (RVS) (Radio Experimental Laboratory). *See* RVS (Rundfunkversuchsstelle) (Radio Experimental Laboratory)
- Furtwängler, Wilhelm, 157
- Gaillard, Marius-François, 164
- Galli-Curci, Amelita, 54
- galvanometers, 81–82
- Gassmann, Remi, 206, 228



- Gauterin, Gustav, 76  
*Gebrauchsmusik*, 1, 10, 38, 98  
“Gegen Zentralisierung” (“Against Centralization”), 28–29  
Geißler, Ewald, 28  
Geist, 184–185  
General Electric (GE), 92, 95  
Genzmer, Harald: authenticity and, 219; Konzerttrautonium and, 163, 164, 170, 176; Mixturtrautonium and, 199–200; photograph of, 171*f*; Sala and, 172  
Gerlach, Walther, 92  
German Amateur Radio Society, 100  
German Democratic Republic, 229  
German idealism, Bildungsbürgertum and, 12–13  
German National People’s Party, 150  
German October, 22  
German radio: accessibility of, 30–32; acoustical distortions and, 3; advertising, 25; audience of, 24, 30–32; broadcasting hours, 33; broadcasts on, 33–35; decentralization of, 27–28, 30; Funk-Stunde Berlin, 20, 35–37; Funk-Stunde Berlin and, 35–37; headphones, 30–31; history of, 22–26; impartiality of, 12, 27–28, 30; license fees, 24; loudspeakers, 30–31; mediator role of, 35–36; Ministry of the Post Office and, 11; network of, 26*f*; *Neue Sachlichkeit* (New Objectivity) and, 37–39; news broadcasts, 24; opening concert for, 20–22, 21*f*; origins of, 2; popularity of, 24–25; purpose of, 26–30; range of, 24; regulation of, 27–28  
German Social Democratic Party, 155  
Germann, Walter, 131  
Gernsback, Hugo, 144  
Giesecke, Heinrich, 152  
Giesecking, Franz Clemens, 177  
Goebbels, Joseph: Hindemith and, 157–158; Konzerttrautonium and, 163; radio and, 151–152; RVS and, 156; steely Romanticism and, 10, 178; technology and, 148; trautonium and, 179  
Goethe, Johann von, 13, 184–185, 190  
Goeyvaerts, Karel, 224  
“good music,” 151  
Google Assistant, 42  
Goslich, Siegfried, 183, 223  
Gottheiner, Viktor, 106  
Gottlieb Coradi, 71, 72*f*  
Graef, Karl, 111  
*Grammophonmusik*, 107–108  
gramophones, 36, 48, 107  
Gredinger, Paul, 224  
Griep, Günter, 190  
Griessing, Otto, 158  
Gronostay, Walter, 104  
Gropius, Walter, 97  
Grosch, Neil, 9–10  
Grunel, Friedrich Wilhelm, 111–112  
Grützmaker, Martin, 86, 94, 114  
Gsovsky, Tatiana, 206  
Guarneri Quartet, 34  
Guidelines of Radio Reform, 150–151  
Gutzmann, Hermann, Sr., 68  
Hába, Alois, 132  
Haber, Fritz, 97  
Hadamovsky, Eugen, 152  
Haentzschel, Kurt, 27  
Haffner, Sebastian, 22  
Hafner, Erhard, 213  
Hagemann, Carl, 30, 59  
Hahn, Otto, 97  
*Hallformanten*, 132–137, 137*f*, 140  
Hammerstein, Adolf, 146  
Hammes, Fritz, 208  
Hammond Novachord, 6  
Handel, George Frideric, 146  
Häntzschel, Georg, 177  
Harbou, Thea von, 160  
Harlan, Veit, 203  
harmonic analyzers, 65, 71–73, 72*f*, 75, 80  
harmonic partials, 67  
harmonic theory, 68–69  
harmonics, 46  
*Harmonious Triads* (Jackson), 15  
harmoniums, 47–48  
Hårt, Mikael, 44  
Hartmann, Hanns, 212  
*Hausmusik* (house music), 6  
Hausrath, Herbert, 114–115  
Havemann, Gustav, 39, 157  
Havemann Quartet, 34  
Haydn, Joseph, 7, 20, 61  
headphones, 30–31  
hearing, 124–126  
Heger, Robert, 188  
Heilmann, Ernst, 27

- Heinrich Hertz Institute for Oscillations Research (HHI), 78, 155  
heliophon, 131  
Hellberger, Bruno, 124  
hellertion, 124, 131, 146  
Helmholtz, Hermann von: influence of, 139–140; overtone theory, 133; research of, 66–69; theory of formant formation, 131–133, 135, 182, 223; theory of hearing, 199; theory of resonance, 4; work on physiology, 15  
Henrici, Olaus, 71, 72*f*  
Herf, Jeffrey, 116  
Hermann, Ludimar: influence of, 139; research of, 67–69; theory of formant formation, 84, 132–133, 137, 140; theory of impulse excitation, 4, 135, 141, 182  
Hernried, Robert, 51  
Herrmann, Bernard, 226  
Hertz, Gustav Ludwig, 97  
Herzfeld, Friedrich, 201  
Herzog, Friedrich, 157  
heterodynes/heterodyning, 75, 80–81, 86, 123  
heterodyning, 123  
Hettner, Gerhard, 146  
Heurich, Hugo, 169  
Hindemith, Paul, 3, 60, 132; Brecht and, 156; compositions of, 141*f*, 143, 156, 157, 161, 164; Exhibition of Degenerate Music and, 153; Fleisch and, 35; Internationale Gesellschaft für neue Musik (International Society for Contemporary Music) and, 37; Nazi Party and, 156–158; Neue Musik Berlin 1930 festival, 140–141; Neue Musik (New Music) Berlin festival, 1; *Neue Sachlichkeit* (New Objectivity) and, 38; opening concert for the RVS, 100–101; photographs of, 2*f*, 130*f*; research of, 107; *Rundfunkmusik* (radio music) and, 60; Sala and, 119, 158, 160; works by, 33, 98  
Hindenburg, Paul von, 150  
Hitchcock, Alfred, 2, 226–228, 227*f*  
Hitler, Adolf: Beer Hall Putsch, 23; on non-Aryan influence on the arts, 157–158; Wagner and, 153, 201  
*Hochdeutsch*, 12, 28  
Hofmüller, Rudolf, 175  
Holl, Karl, 143  
Hollander-Lossow, Else von, 190  
homosexuality, 203  
Honegger, Arthur, 123, 176, 188  
Höpfner, Karl, 52  
Horkheimer, Max, 62  
Horosko, Marian, 206  
*Hörspiele* (radio dramas), 34  
Huchel, Peter, 190  
Hui, Alexandra, 14  
human perception: role of, 8; study of, 183–184; synthesis and, 124–126  
Huth, Arno, 121  
Hütter, Ralf, 230  
Huxley, Aldous, 16  
hyperinflation, 23  
imitation, 18, 125, 150, 159, 161, 174, 181, 195, 199, 201, 206, 226; quality of, 10–11; role of, 187  
impulse (or shock) excitation theory, 68–69, 132, 135  
*The Indian Tomb* (Lang), 1, 205  
industrial folk music, 230  
industrialization, liberal modernity and, 13  
infidelities: overview, 44–51; Adorno and, 61–64; politics of, 51–53; *Rundfunkmusik* (radio music) and, 57–61; sopranos and, 53–57. *See also* fidelity  
Ingenbrand, Josef, 177, 178  
Institute for Oscillations Research, 155  
instruction (*Belehrung*), German radio and, 27, 33–35, 36  
intellectual property, 166, 168, 183, 218, 219  
interference tubes, interference apparatus, 69, 70*f*, 77, 96, 108–109  
International Society for Contemporary Music (ISCM) (Internationale Gesellschaft für neue Musik), 37–38, 156–157  
Iverson, Jennifer, 16, 214  
Ives, Charles, 38  
Jäger, Herbert, 168  
“Japanische Festmusik” (“Japanese Celebratory Music”) (Strauss), 176  
Jarnach, Philipp, *Neue Sachlichkeit* (New Objectivity) and, 39  
*Jeanne d’Arc au bûcher* (Honegger), 188  
Jeans, James, 84  
Jensen Company, 93  
Jeritz, Maria, 54

- Joachim, Heinz, 169  
Jung, Cläre, 190  
Just, Paul, 114
- Kampfbund für deutsche Kultur (Militant League for German Culture), 156  
Kant, Immanuel, 13  
Kapeller, Ludwig, 99, 104  
Karl, Friedrich, 28  
Kellogg, Edward W., 92  
Kelvin, Lord, 71  
Kestenberg, Leo, 104, 131–132  
keyboard instruments, 82, 119, 123, 127, 143, 169, 224, 229, 232  
Khrushchev, Nikita, 229  
Kirschninck, Heinz, 174  
Kittel, Bruno, 155  
Klangfilm GmbH, 131  
*Klangtreue* (faithful to sound), use of term, 9  
*Kleinbürger*, 44  
Knöpfke, Friedrich Georg, 20  
Kochan, Günter, 189  
Koeßler, Paul, 186  
Koestler, Arthur, 146  
Köhler, Wolfgang, 65, 146  
Kolhöster, Werner, 146  
“Kompositionen für elektrische Stimmen” (“Compositions for Electric Voices”) (Borris), 103  
König, René, 186  
Königs Wusterhausen radio station, 23, 25, 45, 111  
Konzertinstrument, 162, 163*f*, 164, 168–170, 174, 189; invention of, 162–163; photograph of, 163*f*; subharmonics and, 162  
Konzerttrautonium, 13, 18, 140, 162, 170, 171*f*, 172, 174–177, 187–188; debut of, 172; invention of, 170–172; photographs of, 171*f*, 192*f*  
Körting & Mathiesen AG, 112  
Kraft durch Freude (KdF), 13, 175–177  
Kraftwerk, 230  
Kreichgauer, Alfons, 106, 116  
Kreisler, Fritz, 20  
Krenek, Ernst, 132; Internationale Gesellschaft für neue Musik (International Society for Contemporary Music) and, 37; *Neue Sachlichkeit* (New Objectivity) and, 39  
Krigar-Menzel, O., 136  
*Kultur*, 185  
Kulturgemeinde (Strength Through Joy—Cultural Community), 175  
Kulturträger, 13, 36, 39, 44, 66, 101, 185  
“Das Kunstwerk im Zeitalter seiner technischen Reproduzierbarkeit” (“The Work of Art in the Age of Mechanical Reproduction”) (Benjamin), 62  
Kursell, Julia, 14–15  
“Kutz gohscht na” (Spätzle), 29
- Labyrinth* (Majewski), 203–205  
Lade, Ludwig, 174  
Laemml, Whitney, 206  
Lammers, Aloys, 99–100  
Lang, Fritz, 1, 97, 205  
“Langsames Stück und Rondo für Trautonium” (“A Slow Piece and Rondo for the Trautonium”) (Hindemith), 164  
Larsén-Todsen, Nanny, 54  
Laue, Max von, 97  
Lawrence, Harold, 207  
Lazarsfeld, Paul, 62  
LC circuits, 76–77, 85, 121  
Lehmann, Herbert, 163  
*Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (*On the Sensations of Tone as a Physiological Basis for the Theory of Music*) (Helmholtz), 66  
*Lehrstücke* (lesson pieces), 38  
Leithäuser, Gustav Engelbert, 78, 100–101, 155  
Lenzola-Lautsprecher-Fabrik, 113  
Lertes, Peter, 124, 131  
liberal modernity: industrialization and, 13; status of, 44  
liberalism, 148  
license fees, 24  
Lichtenthal, Herbert, 101  
“Lindbergh-Flug” (“Lindbergh Flight”), 60  
Lion, A., 121, 141  
List, Karl, 169  
“Literatur und Runkfunk” (“Literature and Radio”) (Döblin), 61  
Loewe, 31  
*Lohengrin* (Wagner), 50  
loudspeakers: accessibility of, 30–31; improvements to, 92–95; quality of, 46, 56; range of, 87*f*; tower illustration, 166*f*; used by RVS, 106, 112–113

- Love Parade, 230  
Lubsznynski, Günther, 41  
Ludendorff, Erich, 23  
Ludwig, Karl-Heinz, 149  
Luening, Otto, 5  
Luft, Friedrich, 191  
Luftrum Sound Design, 232  
Lyrebird, 233
- Maasz, Gerhard, 175  
machine learning, 232  
*Madame Butterfly*, 23  
Mager, Jörg, 3, 123, 154–155  
*Magic Mountain* (Mann), 43  
Magnetophon, 106  
Magnus, Kurt, 28–29, 152  
Majewski, Hans-Martin, 190, 203  
Mann, Thomas, 43, 153–154  
Mark I and II synthesizers, 5, 122  
Martenot, Maurice, 123, 223  
Martenot waves, 6, 123, 176, 188  
Martin, John, 207  
Marx, Karl, 43  
*Maschinist Hopkins* (Brand), 230  
“The Mathematical Theory of Communication” (Shannon and Weaver), 215  
Mathews, Max, 5  
*Mathis der Maler* (Hindemith), 156, 157  
Mayer, Emil, 131  
Mayer, Jörg, 85  
McCartney, Paul, 232  
*Mecklenburgisch* (Mecklenburg), 29  
Meitner, Lise, 97  
melochord, 215  
*Melos*, 143  
Mendelsohn, Erich, 97  
Mendelssohn, M. Felix, 99  
Mendelssohn-Bartholdy, Felix, 20  
Menzerath, Paul, 214  
Messiaen, Olivier, 3, 38, 123  
Meyer, Erwin: on electroacoustics, 3, 73; on fidelity, 41–42; influence of, 139; research of, 65, 80–84, 83f, 92–94, 114; on sound analysis, 75  
Meyer-Eppler, Werner, 187, 211, 214–221  
microphones: carbon microphones, 47, 50, 103; condenser microphones, 79; improvements to, 85–92; moving-coil microphones, 92; quality of, 87f, 88f; ribbon microphones, 90–92; used by Funk-Stunde Berlin, 91f; used by RVS, 106, 110–112  
Miller, Dayton Clarence, 71–73, 72f, 139  
Miller, Oksar von, 146  
Ministry of Public Enlightenment and Propaganda, 175  
Ministry of the Interior. *See* Reichsministerium des Innern (RMI) (Reich’s Ministry of the Interior)  
Ministry of the Post Office, 11, 23–24, 27, 78, 97–98  
*Mit Farben begann es* (*It Began with Colors*), 205  
*Mitteldeutsche National-Zeitung*, 178  
Mitteldeutscher Rundfunk (MDR), 196  
mixture trautionium. *See* Mixturtrautionium  
Mixturtrautionium, 1; components of, 5; genres of, 201–207; improvements to, 228–229; invention of, 196–201; photographs of, 197f, 227f  
modernism, 15, 126, 153, 185, 207–209, 232  
Moholy-Nagy, László, 39  
Mommsen, Wolfgang, 44  
monochord, 223  
Moog, Bob, 230  
Moog synthesizers, 5, 14, 122  
Moogtonium, 230  
Moore, C. R., 75  
Moore, Grace, 53  
Morgenroth, Alfred, 164, 170  
Movietone sound system, 93  
moving-coil microphones, 92. *See also* microphones  
Mozart, Leopold, 146  
Mozart, Wolfgang Amadeus, 20, 61, 101  
Müller, Ludwig Richard, 189  
Müller-Hartmann, Robert, 61  
Mumford, Lewis, 42  
*Music, Sound, and the Laboratory from 1750 to 1980* (Hui, Kursell and Jackson), 14  
*Music and the Making of Modern Science* (Pescic), 14  
“Music on New Paths” (Varèse), 215  
musical aesthetics: politics and, 11; theme of, 6–7; Trautwein and, 183–187  
musical instruments: early electric, 122–124; fidelity and, 41, 48–51; materiality of, 14; tone color of, 4, 7, 9, 16, 47–48, 51, 57, 61–63, 67, 70f, 82–84, 100, 107–108, 112,

- 116–118, 124–125, 141–142, 150, 158–161,  
170, 195, 231  
*Die Musik*, 157  
*Musik und Technik*, 156  
*Musikblätter des Anbruch* (Musical Sheets of  
the Dawn), 61  
musique concrète, 18, 205, 211–212, 216,  
219–220, 222
- National Socialism, 148, 152  
National Socialist German Workers' Party,  
148–149  
Nationalsozialistischer Bund Deutscher  
Technik (National Socialist Association  
for German Engineering), 184  
*Naturtreue* (faithful to nature), 9, 41, 51, 79,  
104, 110  
Nazi Party: electric music and, 6, 149–150;  
engineers and, 214; German radio and, 3;  
Hindemith and, 156–158; imitation and,  
10; physicists and, 214; radio and, 150–153;  
RVS and, 155–162; Sala and, 172–180;  
Trautwein and, 13, 153–155, 165  
Nelson, Edward L., 40, 50  
Neo-Bechstein grand piano, 123, 146  
Nernst, Walther, 85, 146  
Nesper, Eugen, 53  
Nestel, Werner, 212  
*Eine neue Epoche der Musik durch Radio*  
(*A New Epoch of Music by means of*  
*Radio*) (Mager), 3, 123  
neue Musik, 37–38  
Neue Musik Berlin 1930 festival, 107, 140–143  
*Neue Sachlichkeit* (New Objectivity), 9–10,  
37–39, 98  
Neumann, Georg, 89  
news broadcasts, 24  
Niebling, Hugo, 205  
*Niederfränkisch* (Low Franconian), 29  
Nordischer Rundfunk AG (Northern Radio  
Corporation) (NORAG), 29–30, 61  
*Nordniedersächsisch* (North Low Saxon),  
29  
Die Novembergruppe (November Group),  
39
- Office of Telegraph Technology, 23, 98, 100  
Olson, Harry F., 5, 90, 122  
*Olympia* (Riefenstahl), 104  
Olympic Games, 165
- “On Acoustical Problems from the Fron-  
tiers (Grenzgebieten) of Music, Physics,  
and Physiology” (Trautwein), 117  
ondes Martenet, 6, 123, 176, 188  
opera broadcasts, 23, 34–35, 49–50, 59  
Oranienburg concentration camp, 152  
Orff, Carl, 1, 199–200, 201  
“Organic Formation of the Economy: An  
Engineer’s Assignment” (Schult), 149  
organs, 15  
Ortega y Gasset, José, 185  
oscillograms, 137*f*, 138*f*, 139*f*  
oscillographs: distortions and, 95; Meyer  
and, 81; quality of, 65; Schünemann and,  
108–110; vowel sounds and, 71, 74  
*Ostfälisch* (Eastphalian), 29  
Otto Knöllrer, 113  
overtones, 76–77, 80, 87, 133
- Paganini, Niccolò, 172–174, 175  
Pama Paper Maché Company, 113  
*Parsifal* (Wagner), 191, 201–202  
partials (and upper partials), 46, 67, 71, 85, 125  
Patteson, Thomas, 14, 162  
Pemberton, Cecilia, 57  
people’s trautionium. *See* Volkstrautionium  
performers, 5  
Pesic, Peter, 14  
Pfeiffer, Christian A., 178  
Philadelphia’s Academy of Music, 93  
phoniatrics, 68  
phonogeny, 49  
phonographs, 44–45  
phonomontages, 219–220  
physiological aesthetics, 15  
pianos, 48, 82, 123–124, 146  
Pichler, Peter, 231  
piezoelectric speakers, 95  
Pinch, Trevor, 14  
pitch, 46  
Planck, Max, 97  
plastic, 205  
*Plattdeutsch* (or Low German), 29  
plucked instruments, 82  
politics: musical aesthetics and, 11; turmoil  
and, 11–12  
Ponselle, Rosa, 54  
Poullin, Jacques, 224  
Pousseur, Henri, 224  
Prieberg, Fred K., 199, 209

- Princeton Radio Project, 62  
propaganda: German radio and, 3, 12;  
“Stunde der Nation” (“The Nation’s  
Hour”), 152; trauttonium and, 175  
Protos, 112  
proto-synthesizers, 5  
Prussian Ministry of Culture, 3, 78, 98, 100,  
103  
*Puck* (Delannoy), 191  
*The Pulse of Modernism* (Brain), 15
- Raabe, Peter, 164, 170  
radio: distortions and, 56; licenses, 21–25,  
32, 152; Nazi Party and, 150–153;  
operators, 57. *See also* German radio  
Radio Act (1927), 55  
Radio City Music Hall, 93  
Radio Company Erich & Grätz, 115  
Radio Corporation of America (RCA), 95  
radio dramas, 60, 196  
Radio Exhibition of 1932, 124  
Radio in the American Sector (RIAS), 13  
radio stations: improvements to, 76;  
increase in, 25, 53  
“The Radio Symphony: An Experiment in  
Theory” (Adorno), 62  
radio trauttonium. *See* Rundfunktrauttonium  
*Radio-Craft*, 144, 145*f*  
Radio-Loewe, 115  
Radio-Stunde Berlin, 33  
Raps, A., 136  
Raven-Hart, R., 99  
RCA Victor Company, 90  
reactionary modernism, 116  
realism, 193  
Realschulen, 76  
reed pipes, 15, 66–67  
reel-to-reel tape, 190, 199, 203–204  
Reger, Max, 163  
regional dialects, 29–30  
Rehding, Alexander, 7, 14  
Reichsministerium des Innern (RMI)  
(Reich’s Ministry of the Interior), 27–28  
Reichsmusikkammer (Reich Chamber of  
Music), 13, 157, 164, 170  
Reichs-Rundfunk-Gesellschaft (Reich’s  
Broadcasting Corporation), 3, 25–26, 60,  
103  
Reinhardt, Max, 190–191  
Reis, Johann Philipp, 75  
*Eine Reise zum Mond* (*A Journey to the  
Moon*), 205  
Reisz, Eugen, 89, 100, 111–112  
resonance formants. *See* *Hallformanten*  
resonant circuits, 76–77, 133–134, 134*f*  
Rethberg, Elisabeth, 54  
*Das Rheingold* (Wagner), 201–202  
rhythm, 47  
rhythmicon, 144  
ribbon loudspeakers, 92  
ribbon microphones, 90–92. *See also*  
microphones  
Rice, Chester W., 92  
Rice-Kellogg loudspeakers, 112  
“Richtlinien für die Regelung des Rund-  
funks” (“Guidelines for the Regulation  
of Radio”), 27  
Rider, John F., 53–54  
Riedler, Alois, 116  
Riefenstahl, Leni, 104, 144  
Riegger, Hans, 79, 92  
Riesenblatthaller loudspeakers, 113  
Riethmüller, Helmut, 178  
*Ring der Nibelungen* (Wagner), 59  
Ringer, Fritz, 44  
Ritter, Oswald, 112  
Robertson, Peggy, 228  
Rockefeller Foundation, 62  
Roedemeyer, 28  
Rohe, Ludwig Mies van der, 97  
*Röhrenortempfänger*, 31  
Rosbaud, Hans, 143, 199  
Rosé Quartet, 34  
*Rosemary* (Thiele), 205  
Rosenberg, Alfred, 156  
Rousseau, Jean-Jacques, 7  
Royal Albert Hall, 100  
Rudolph, Dietmar, 228  
Ruhr region, 22  
*Der Rundfunk* (*The Radio*), 189  
*Rundfunk Jahrbuch*, 30  
*Rundfunkkunst* (radio art), 57  
*Rundfunkmusik* (radio music), 1; develop-  
ment of, 3, 5, 39; fidelity problems and,  
45; infidelities and, 57–61; support of,  
104  
Rundfunktrauttonium, 1; invention of,  
166–177; photograph of, 167*f*  
Runge, Gertrud, 174  
Russell, William, 228

- Rutenborn, Günter, 196
- RVS (Rundfunkversuchsstelle) (Radio Experimental Laboratory): amplifiers used by, 106, 113–114; demise of, 156; experimentation and, 106–108; fidelity and, 108–110; Flesch and, 33; founding of, 98–106; funding for, 3, 103; Funk-Stunde Berlin and, 101; loudspeakers used by, 106, 112–113; microphones used by, 106, 110–112; Nazi Party and, 155–162; objective of, 101; opening concert for, 101, 102*f*; opening of, 3; photograph of, 105*f*; Sala at, 119–120; Trautwein at, 114–120; uniqueness of, 6
- Sacia, C. F., 73–74
- Saint-Saëns, Camille, 20
- Sala, Oskar: Annual Musicians Conference of the General German Music Association, 164; authenticity and, 217–221; biographical sketch of, 119, 187–188, 228–229; *The Birds* (Hitchcock), 2; Cologne Studio of Electronic Music of Nordwestdeutscher Rundfunk (NWDR) and, 220–221; drafting of, 179; Eimert and, 222–223; hearing of, 113; Hindemith and, 119, 158, 164; Hitchcock and, 226–228; on imitation, 187; improvements to the trautonium, 146; on interpretation, 220; invention of the trautonium, 1, 129–130, 133; Konzerttrautonium and, 162–163, 173*f*; and later models of the trautonium, 10; Meyer-Eppler and, 214, 221–222; Mixturtrautonium and, 196–207; on modern synthesizers, 5–6, 122; Nazi Party and, 172–180; Neue Musik Berlin 1930 festival, 140; patents obtained by, 198; photographs of, 2*f*, 130*f*, 167*f*, 171*f*, 227*f*; postwar years, 187–190; promotion of the trautonium, 13–14; RVS and, 119–120; studio of, 203, 204*f*, 227*f*; subharmonics and, 162; theory of formant formation, 139–140; Trautwein and, 168, 182–183, 189; Volkstraonium and, 158, 161. *See also* trautonium
- Salinger, Hans, 81
- Schaeffer, Pierre, 5, 211, 220, 224
- Schael, Gerhard, 188
- Scharnagl, Karl, 146
- Scheffers, P., 219
- Schenk, Julius, 185
- Schenk, Wilhelm, 146
- Scherchen, Hermann, 60, 182, 192
- Schiller, Friedrich, 13
- Schillinger, Joseph, 3
- Schlemm, Gustav Adolf, 170, 178
- Schmidt, Rudolf, 1, 2*f*, 140–141, 163
- Schneider, Peter Otto, 202
- Schneider-Esleben, Florian, 230
- Schoen, Ernst, 47, 49
- Schoenberg, Arnold, 132; compositions of, 5; Exhibition of Degenerate Music and, 153; Internationale Gesellschaft für neue Musik (International Society for Contemporary Music) and, 37–38
- Scholz, Erich, 150
- Schonger, Hubert, 202
- Schottky, Walther H., 90, 92
- Schreiber, Ernst, 229
- Schreker, Franz: Internationale Gesellschaft für neue Musik (International Society for Contemporary Music) and, 38; *Neue Sachlichkeit* (New Objectivity) and, 39; *Rundfunkmusik* (radio music) and, 60
- Schrödinger, Erwin, 97, 146
- Schroter, Manfred, 185
- Schubert, Franz, 61
- Schult, Heinrich, 149
- Schulz, Karl, 212
- Schulz-Dornburg, Rudolf, 175
- Schumann, Robert, 20
- Schünemann, Georg: on distortions, 41, 45, 47; film industry and, 205; radio broadcasting equipment and, 108–110; resignation of, 155; *Rundfunkmusik* (radio music) and, 59–60; RVS and, 99–101, 103–106, 107; theory of formant formation, 139; trautonium and, 127, 130–131, 162
- Schuricht, Carl, 172
- Schütz, Heinz, 213
- Schwarz Hörer*, 24
- Der Schwingkreis: Schaltungsgeschichten an den Rändern von Musik und Medien* (Dörfling), 15
- Scientific American*, 53
- search frequency (*Suchfrequenz*), 80
- search tone (*Suchton*), 80–81
- SED (Socialist Unity Party of the German Democratic Republic), 193
- Seidler-Winkler, Bruno, 111
- Sell, Hellmut, 103

- Semmelroth, Wilhelm, 212  
Shannon, Claude, 215  
shock excitation. *See* impulse (or shock)  
  excitation theory  
sideband suppression, 56  
Siebert, Friedrich, 208  
Siebs, Theodor, 28, 151  
*Siegfried* (Wagner), 49  
Siemens, Daniel, 148  
Siemens & Halske: amplifiers, 50; harmonic  
  analyzers, 78–79; loudspeakers, 50, 95;  
  Ministry of the Post Office and, 23; RVS  
  and, 106, 112–113  
Siemens-Schuckert, 76  
sine tones, 213–214  
singing-voice generators, 233  
Siri, 42  
Skorzeny, Fritz, 178  
Social Democratic Party, 27  
Socialist Unity Party of the German  
  Democratic Republic (SED), 193  
sopranos, 53–57  
soullessness, 177, 190, 200  
sound effects, 1, 144, 176, 191, 226–228  
sound envelope, 7, 84  
sound intensity, 90  
sound reproduction, 42  
sound synthesis and analysis, 66, 71–73  
*Sounding Bodies* (Pesci), 14  
*The Soundscape of Modernity* (Thompson), 8  
Spätzle, Michael, 29  
speech sounds, 4, 67, 71, 74–78, 92, 108, 118,  
  132, 135–137, 140, 216  
Spengler, Oswald, 184  
“Sphärenmusik—Was ist ein Trautonium?”  
  (“Music of the Spheres—What is a  
  Trautonium?”), 177  
spherophone, 3, 123, 154  
Spix, Jörg, 230  
“Sprachpflege im deutschen Rundfunk”  
  (“Concern for the Purity of Language in  
  German Radio”), 151  
Sprechapparat, 106  
Staatliche akademische Hochschule für  
  Musik (Berlin Academy of Music).  
  *See* Berlin Academy of Music  
*Stahl—Thema mit Variationen* (Steel:  
  *Variations on a Theme*) (Niebling),  
  205  
Stalin, Joseph, 193  
steely romanticism aesthetic, 6, 10, 148, 178,  
  180  
Stege, Fritz, 142  
Steidle, Hans Carl, 41, 50  
Stein, Fritz, 156  
Steinberg, John C., 54–55  
Steiner, Rudolf, 185  
Steingraeber, Eduard, 191  
Steinhauser, Walter, 172, 174  
Steinke, Gerhard, 229  
Stern, Fritz, 154  
Stern, Julius, 156  
Sterne, Jonathan, 8, 42, 110  
Stille, Curt (Kurt), 106  
Stockhausen, Karlheinz, 5, 213–214, 224, 230  
*Stoßerregung*. *See* impulse (or shock)  
  excitation theory  
Strauss, Johann, 101  
Strauss, Richard, 59, 153, 157, 176  
Stravinsky, Igor, 33, 98, 132, 218  
Stresemann, Gustav, 11–12  
Stromberg-Carlson Telephone Manufactur-  
  ing Company, 56  
Struwelpeter, 185  
Stuckenschmidt, Hans Heinz, 38–39, 196,  
  199, 213  
Studiengesellschaft für Schwingungsforsch-  
  ung (Research Association for  
  Oscillations Research), 78  
Studio for Electronic Music of Northwest-  
  deutscher Rundfunk (Northwest  
  German Radio, NWDR), 182  
Stumpf, Carl, 17, 73, 76, 79, 85, 96, 106, 116,  
  125, 130, 140; influence of, 139; interfer-  
  ence method, 108–109; research of, 65,  
  69, 70f; trautonium and, 139  
“Stunde der Nation” (“The Nation’s Hour”),  
  152  
*Stürme über dem Mont Blanc* (*Storm over*  
  *Mont Blanc*) (Fanck), 144  
subharchord, 229–230  
subharmonicon, 230  
subharmonics, 162, 168, 171, 198, 229  
subjective tones, 8  
Süddeutscher Rundfunk, 34  
Südwestdeutscher Rundfunk (Frankfurt am  
  Main), 33, 34  
synthesizers: history of, 5; Mark I and II  
  synthesizers, 5, 122; Moog synthesizers, 5,  
  14, 122; trautonium and, 122, 230



- SynthGPT, 232  
Szendrei, Alfred, 51  
Szilard, Leo, 97
- tape music, 190, 199, 203–204  
Tchaikovsky, Pyotr Ilyich, 20  
“Technically and Creatively Transformed”  
(Heinz Joachim), 169  
Technische Hochschule Berlin (THB)  
(Technical University of Berlin), 78  
technology: art and, 184–187; culture and,  
44; importance to the Reich, 148, 165  
Telefunken: imitation and, 10; loudspeakers,  
95; Ministry of the Post Office and,  
23; Rundfunktrautonium and, 166; Volk-  
strautonium and, 131, 160–161; Wagner  
and, 76; Wireless Economic Broadcasting  
Service (Wirtschaftsrundfunk) and, 24  
telharmonium, 122  
Tempel-Lautsprecher-Fabrik, 113  
Termen, Lev Sergeevich, 3, 122  
theater music, 1  
Théberge, Paul, 2, 144  
theremin, 3, 6, 122–123  
Thiele, Rolf, 205  
Thierfelder, Franz, 28  
Third Reich, 9  
Thompson, Emily, 8, 45  
Thomson, Virgil, 63  
*Threepenny Opera* (Brecht), 149–150  
Thuras, A. L., 92–94  
*Thüringer Allgemeine Zeitung*, 176  
thyratrons, 158, 169, 171, 198  
Tiessen, Heinz, 39  
timbre. *See* tone color  
Tkaczyk, Viktoria, 15  
Toch, Ernst, 3; *Grammophonmusik* and,  
107–108 *Neue Sachlichkeit* (New  
Objectivity) and, 38 *Rundfunkmusik*  
(radio music) and, 60  
tone color, 164; Beethoven’s use of, 62–63;  
defined, 7; fidelity of, 46; history of, 5; of  
musical instruments, 4, 7, 9, 16, 47–48, 51,  
57, 61–63, 67, 70f, 82–84, 100, 107–108, 112,  
116–118, 124–125, 141–142, 150, 158–161, 170,  
195, 231; understanding of, 4; of vowels  
and human voice, 66–67, 107, 129, 131  
trautonium: aesthetic qualities, 9–10;  
broadcasts of, 155; building instructions  
for, 144, 145f, 155; circuit diagram for,  
135–136, 136f; compositions for, 162;  
debut of, 140–147; formats and, 132–140;  
funding for, 131–132, 153; improvements  
to, 146, 162–165; invention of, 121–122;  
materiality of, 14; Neue Musik Berlin  
1930 festival, 140; Neue Musik (New  
Music) Berlin festival, 1; origin of, 2;  
original, 126–132; photographs of, 127f,  
128f; popularity of, 1, 10, 143; postwar  
years, 190–196; propaganda and, 175;  
sound effects, 1, 144, 176, 191, 196, 226–228;  
subsidization of, 13; timbres of, 131; unique-  
ness of, 6; versatility of, 10. *See also*  
Trautwein, Friedrich Adolf  
“Das Trautonium: Prozesse des Technologietransfers im Musikinstrumentenbau”  
(Brilmayer), 15  
*Trautonium-Schule* (Trautonium School),  
161  
Trautwein, Friedrich Adolf: biographical  
sketch of, 114–119, 181–182, 187; Cologne  
Studio of Electronic Music of Nordwest-  
deutscher Rundfunk (NWDR) and,  
220–221; education of, 13, 114–116; Eimert  
and, 222–223; human perception and,  
124–126; on imitation, 187; impulse exci-  
tation theory and, 135; influences on, 139;  
invention of the trautonium, 1; Meyer-  
Eppler and, 221–222; musical aesthetics  
and, 183–187; *Musik und Technik*, 156;  
Nazi Party and, 13, 153–155, 165; patents  
obtained by, 116, 166, 189; n phonomontages,  
220; photographs of, 2f, 127f, 130f;  
promotion of the trautonium, 13; RVS  
and, 104, 114–120; Sala and, 168, 189;  
theory of formant formation, 139; and  
the theory of impulse excitation, 4;  
Volkstrautonium and, 161. *See also*  
trautonium  
treble speakers, 93  
Trendelenburg, Ferdinand, 78–79, 136,  
140  
Tresch, John, 14, 135  
*Treue* (term, faithfulness), 9  
triodes, 95  
Trocco, Frank, 14  
Tschirner, Hans, 113  
tuning forks, 66–67  
turntablism, 107  
tweeter units, 93

- Überduck, 233  
“Ueber die Klangfarbe der Vocale” (“On the Tone Color of Vowels”) (Helmholtz), 66  
*Unterhaltungsmusik* (light music), 34, 152  
Ussachevsky, Vladimir, 5
- vacuum tubes, 95, 113
- Varèse, Edgard, 3; Internationale Gesellschaft für neue Musik (International Society for Contemporary Music) and, 38; “Music on New Paths,” 215; use the *ondes Martenot*, 123
- Verband Deutscher Diplom-Ingenieure (VDDI), 44, 116
- Verdi, Giuseppe, 20
- Verein Deutscher Ingenieure, 186  
*Die Verurteilung des Lukullus* (*The Condemnation of Lukullus*) (Brecht and Dessau), 192–194
- very high frequency (VHF) radio broadcasting, 231
- Vienna in the Age of Uncertainty* (Coen), 15
- Vierling, Oskar, 84–85, 140, 155
- violins, 45–46
- Vitaphone sound system, 93
- vocal cords, 66–67
- vocal types, 48–49, 57
- vocoder, 182–183, 215
- Vogel, Vladimir, 39
- voice replication, 233
- voiced-based personal assistants, 42
- Voicemod, 233
- Volksempfänger*, 12, 158
- Volkstrautonium, 1; debut of, 158–162; diagram of, 160*f*; imitation and, 10; photograph of, 159*f*; timbres of, 131
- Von deutscher Tonkunst* (*Of German Musical Art*) (Raabe and Morgenroth), 164
- Voskuhl, Adelheid, 13, 44
- Vossische Zeitung*, 155
- vowel sounds, 67–68, 74, 77, 79, 107, 134
- Vox House, 20–22, 89
- Vox Maschinen AG, 106
- Waetzmann, Erich, 87
- Wagner, Karl Willy, 75–78, 98, 100, 139, 155
- Wagner, Richard, 1, 49, 50, 59, 153, 202
- Wagner, Wieland, 191, 201
- Walter, Fried, 178
- Warburg, Otto Heinrich, 97
- Warschauer, Frank, 59  
“Warszawianka” (“Whirlwinds of Danger”) (Mager), 155
- Watson, Waldon, 228
- Weaver, Warren, 215
- Weber, Max, 43
- Weber, Wilhelm Eduard, 15
- Webern, Anton: compositions of, 5; Exhibition of Degenerate Music and, 153; Internationale Gesellschaft für neue Musik (International Society for Contemporary Music) and, 38
- Wegel, R. C., 73
- Wegel, R. L., 75
- Wehnelt, Arthur, 146
- Weihe, Carl, 44, 149
- Weill, Kurt, 3; Exhibition of Degenerate Music and, 153; fidelity problems and, 51; German radio and, 6, 33; *Neue Sachlichkeit* (New Objectivity) and, 39; *Rundfunkmusik* (radio music) and, 60; RVS and, 103–104; works by, 97, 98
- Weimar Academy of Music, 188
- Weimar Constitution, 23
- Weimar Republic: German radio and, 3; *Zeitoper* and, 10
- Weismann, Genzmer and Julius, 189
- Weissenborn, Hermann, 101
- Welte-Mignon, 38
- Wente, Edward Christopher, 89, 92–94
- Westdeutscher Rundfunk, 212–214
- Western Electric, 6, 73, 89, 93, 95
- Westfälisch* (Westphalian), 29
- Wiener, Karl, 47, 48–49
- Wilhelm II, 13
- Williams, Raymond, 42
- Willisen, H. K. von, 103
- Willnauer, Franz, 201
- Windt, Herbert, 104
- Winkelmann, Joachim, 128, 144
- Winner, Langdon, 42
- Winzheimer, Bernhard, 51
- Wireless Association of America, 144
- Wireless Economic Broadcasting Service (*Wirtschaftsrundfunk*), 24
- Wise, Norton, 15
- Wolf, Rebecca, 14
- Wolpe, Stefan, 39
- women: fidelity problems and, 53–57; roles of, 31–32

- woodwinds, 48, 82  
*World-Radio*, 142  
*Württembergische Zeitung*, 175  
Würzburger, Karl, 111, 151
- X-ray cinematography, 106
- Zahn, Helmut, 228  
“Zauberei auf dem Sender” (“Magic on the  
Broadcasting Station”), 60
- Zeitoper*, 10, 98  
*Zeitschrift des Vereines Deutscher Ingenieure*  
(*Journal of the Association of German*  
*Engineers*), 149  
*Zeitschrift für Musik*, 156  
Zentner, Wilhelm, 174  
Zieritz, Grete von, 189  
*Zivilisation*, 185  
Zschimmer, Eberhard, 44  
Zweig, Stefan, 22