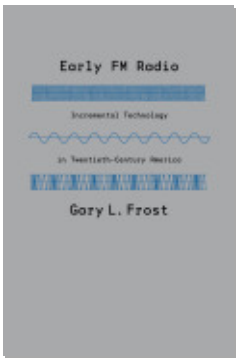
Early FM Radio

Frost, Gary L.



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FM Pioneers, RCA, and the Reshaping of Wideband FM Radio, 1935–1940

"Revolution in Radio"

Title of Fortune *magazine article about wideband FM, October 1939*

A much better title would have been "Civil War in Radio."

RCA engineer Ellison S. Purington, October 1939

In October 1935, more than five months after Howard Armstrong began leaking information about wideband FM to the press, RCA was still promising only more tests, which prompted him to escalate his offensive with a series of public demonstrations. This was an old strategy among radio practitioners. Guglielmo Marconi had taken his revolutionary wireless telegraph to the New York yacht races forty years earlier, and Lee de Forest staged several stunts to sell watered-down shares of his radio companies to gullible investors. Armstrong had done it himself fifteen years earlier. In 1921, as an officer of the Radio Club of America, he participated in the first transatlantic shortwave transmission, among the most widely publicized accomplishments in early twentieth-century telecommunications.

The first public demonstration of FM radio occurred before the New York section of the Institute of Radio Engineers, on the afternoon of 6 November 1935, in the old Engineering Societies Building located in Manhattan. Armstrong wrote to several RCA managers and engineers beforehand, suggesting that the firm use the occasion to announce also that RCA had transmitted facsimile images via FM from the Empire State Building to Haddonfield. As if to confirm Armstrong's suspicion that the company cared nothing about developing—and perhaps even

feared—wideband FM, Charles Young, the RCA Victor engineer who was working with FM facsimile, coyly demurred: "We would not wish to issue any publicity which would detract from your paper." Armstrong replied that he planned to discuss Young's work anyway.[1] In any event, even if he could not parlay his relationship with RCA into broader publicity, Armstrong still hoped to change some minds in the organization, and he convinced several decision makers and influential engineers from RCA, including Murray Crosby, Harry Sadenwater, Harold Beverage, and Ralph Beal, to attend. In fact, Armstrong began his talk by thanking Sadenwater and his wife for the use of their basement, and acknowledging the assistance of several other RCA employees. Perhaps recognizing these individuals, coupled with the favorable impression FM would make on outsiders, might motivate insiders to take another look.

Almost all extant accounts of this demonstration indicate that many in the audience, especially journalists and others unaffiliated with RCA, witnessed for the first time in their lives the reception of a frequency-modulation program. Armstrong stood on a stage; behind him, he had arranged on a dozen or so tables the modules of a prototype FM receiver, interconnected with festoons of cables. The audience saw no FM transmitter, though, because the unit used that afternoon was located in Carman Runyon's house, twenty miles away in Yonkers. Witnesses recalled that Armstrong's longtime Radio Club friend Paul Godley assisted with the apparatus. He had also participated in the transatlantic shortwave demonstration in 1921; for the next several years, he would promote FM as an independent broadcaster.

Effective demonstrations of new technologies tend toward theatricality. Besides reading a draft of the paper that he submitted a few weeks later to the *Proceedings of the Institute of Radio Engineers*, Armstrong had Runyon transmit "staticless" speech from Yonkers. Then Armstrong played sound recordings RCA engineers had recently made on motion-picture film for the purpose of comparing FM with AM reception. For many in the audience, these samples left the greatest impression, because previously their knowledge about FM's superiority over AM came from only a smattering of newspaper and magazine articles. Even Ralph Beal, now RCA's director of research, and among the most skeptical engineer-managers in that company, admitted that "the presentation was especially interesting because of the [recorded-sound] demonstrations." He stated that they "were very effective in showing that the 41 megacycle Empire State channel was entirely free from static, whereas the present [AM] broadcast frequencies were practically blanketed."[2] A long article in *Electronics* similarly described "a very convincing demonstration of the new system. The quality of reproduction was

as good as that of the best broadcast stations, and the interference level, produced by a noise-infested city area, was very low." A "dramatic demonstration," echoed *Communication and Broadcast Engineering*.[3]

The most famous—and by far the most inaccurate—account of Armstrong's performance was written by a man who was not there. Lawrence Lessing claims in *Man of High Fidelity* that the audience heard demonstrations of sound effects that had so far thwarted the best technology available in broadcasting. Armstrong, Lessing writes in 1956, treated his audience to an exhibition of what became "part of the Major's standard repertoire in showing off the remarkable properties of his new broadcasting system":

> A glass of water was poured before the microphone in Yonkers; it sounded like a glass of water being poured and not, as in the "sound effects" on ordinary radio, like a waterfall. A paper was crumpled and torn; it sounded like paper and not like a crackling forest fire. An oriental gong was softly struck and its overtones hung shimmering in the meeting hall's arrested air. Sousa marches were played from records and a piano solo and guitar number were performed by local talent in the Runyon living-room. The music was projected with a "liveness" rarely if ever heard before from a radio "music box." The absence of background noise and the lack of distortion in FM circuits made music stand out against the velvety silence with a presence that was something new in auditory experiences.[4]

Doubtless such an exhibition of realism would have dazzled listeners in 1935, but Lessing's description is almost entirely fictional—or at least premature. In fact, the preceding quote amounted to a paraphrasing of newspaper and magazine articles written about demonstrations of "high-fidelity" FM two years later. No one who attended that day reported hearing reproductions—vivid or otherwise—of crumpled paper, oriental gongs, guitars, pianos, or Sousa marches. Nor could they have, for Armstrong had yet to incorporate the "high-fidelity" circuits into his system that the reproduction of such sound effects requires. In 1935 even live, point-to-point wired high-fidelity sound reproduction remained principally the esoteric hobby of a handful of audiophiles.

It is true that Armstrong was hoping someday to incorporate circuits into his system that would, ultimately, dramatically widen the audio bandwidth of FM. *Communications and Broadcast Engineering* reported that "Professor Armstrong . . . pointed out that due to 'the extremely short wavelengths, it has been possible to transmit all modulation [audio] frequencies from 30 to 16,000 cycles, and to receive them with what engineers call a flat characteristic [i.e., zero distortion],'" a statement that closely comports with the 15,000-cycle flat response of modern

FM.[5] And one of the two wideband FM patents of 1933 had declared that FM was suitable for television or facsimile "where the rates of modulation are much higher than in voice transmission."[6] Further, an NBC engineer recalled fifty years later that in December 1934 NBC widened the audio bandwidth of wired circuits between Radio City and the Empire State Building laboratory from 10,000 to 14,000 cps, "undoubtedly," he asserted, "part of Armstrong's plan to establish and demonstrate FM as a very-high-fidelity system."[7] But no evidence exists that Armstrong used such circuits until 1936, and no one who attended the IRE demonstration reported hearing sound effects that would have required those circuits. At best the audience was served up a sound quality that far exceeded AM's performance in terms of static suppression, but only moderately, if at all, in terms of audio bandwidth—comparable to the audio fidelity of a late-twentieth-century telephone.

Lessing's 1956 account of the talk, however spurious, is nonetheless notable as a historical artifact, for it echoes the strategy to sell FM outside RCA that Armstrong began to piece together after the New York demonstration. Persuading others of the advantages of FM in 1935 presented a daunting challenge. As the largest radio company in the world, RCA commanded unrivaled respect, and Armstrong needed to quash suspicions that the firm's engineers had rejected FM on technological grounds. In fact, RCA did spurn Armstrong FM for technological reasons. That is, too many engineers and managers—Ralph Beal among them—underrated the true potential of the Armstrong system, a colossal error on their part due chiefly to a combination of intellectual inertia and inadequate testing. The company would never admit to such incompetence though, and its prestige was great enough to blunt the plausibility of the truth. Therefore, Armstrong began to assert that RCA acted out of malice and fear and, moreover, that the firm not only declined to back but also opposed FM radio.

At the end of the day, all the RCA men who came to the IRE talk in New York unconvinced left unconvinced. Even Ralph Beal, who had raved over RCA FM's triumph in the 1931 Schmeling-Stribling fight overseas broadcast, now rejected Armstrong FM. His reasons rested, regrettably, on old-fashioned misapprehensions about the relationship between static and the spectrum. Beal reported to Otto Schairer that the quieter reception did not result from using FM instead of AM, but rather because wideband FM operated in the ultra frequencies instead of the noisier parts of the spectrum. "Major Armstrong," he said in making this point, "did not comment on the fact that . . . there is practically no static on the ultra short waves." Beal also implied hucksterism on Armstrong's part, accusing the inventor of using a "considerable display of showmanship for the purpose

of putting over the idea of the wide band system." "In this respect," he told Otto Schairer, who headed RCA's patent department, "I feel that [Armstrong's talk] deviated from a conservative report of a new development to a body of competent engineers."[8]

The IRE demonstration marked several milestones in the history of FM radio technology. First, it was Armstrong's last failed attempt to sell his patents to RCA. Second, the talk signaled the point at which FM ceased being the concern of a single organization. No longer would RCA be the only important locus of FM research. By taking his system to the public, Armstrong had ensured that from now on, his invention would be developed by a wider community of broadcasters, engineers, and corporations, who took to calling themselves "FM pioneers."

By far the two most significant individuals to enroll in this community were John Shepard 3rd, and Paul DeMars, the owner and chief engineer, respectively, of the New England–based Yankee Network. Shepard, one of the greatest broadcast entrepreneurs of the twentieth century, had been elected the first vice president of the National Association of Broadcasters in 1923. During the same year he invented a crucial element of the American system of broadcasting—the network—by leasing long-distance telephone lines from AT&T for the purpose of simultaneously duplicating live programs in remote cities.[9] Radio networks adopted the technique during the late twenties, and it fell out of usage only after World War II, when microwave radio relays (using frequency modulation) replaced wires.

How the Federal Communications Commission regulated AM broadcasting accounted for why Shepard embraced FM. The commission had crafted a policy of extending radio service to remote, usually rural areas by creating an intricate hierarchy of stations. At the bottom were hundreds of short-range, low-power stations with, 250-, 500-, and 1,000-watt transmitters. These operated only during daylight hours when radio waves propagated over relatively short distances. Above them was a smaller group of various classes of stations that broadcast for longer periods of time and with greater power—5, 10, and 50 kilowatts, for example. At the top were privileged, usually 50-kilowatt, twenty-four-hour stations that occupied one of a few dozen "clear channels" that no other broadcaster used, and which interstation interference, therefore, only minimally afflicted. This three-tier arrangement significantly reduced congestion at night and made network programs available to all but a few corners of the country. But by allowing only a small number of chiefly high-power stations to broadcast at night, the FCC effectively relegated most stations to second-, third-, or fourth-class status.

John Shepard represented a large group of broadcasters who resented clear

channels, for primarily economic reasons. A commercial station made money from airing commercials, and the larger its audience, the more a station could charge for advertising. How many potential listeners a station reached depended in turn on a matrix of factors, including listener ratings and network affiliation, but the most important by far was how high a station ranked in the FCC's hierarchy. The principal station of Shepard's Yankee Network held a regional license, which permitted 50 kilowatts of power, the legal maximum, but like all regionals, it shared its channel with other stations, so that when the radiation patterns of another station on the same channel overlapped, the programs of both were ruined. Because this kind of interference never affected a clear-channel broadcast, virtually all regional stations earned substantially less revenue than a clear-channel station. To make matters worse for Shepard, none of the handful of clear-channel broadcasters in New England was likely to give up its license voluntarily. This state of affairs drove him to political activism. In 1938 Shepard was elected the first president of the National Association of Regional Broadcast Stations, an organization that supported a policy of minimizing the number of clear-channel licensees.[10]

FM provided non-clear-channel broadcasters like Shepard the hope of rendering wattage and clear channels all but irrelevant. Because the range of even a high-power, high-frequency station was limited to a few dozen miles beyond the horizon—day or night—all FM stations were local ones. To be sure, as a regional AM broadcaster, Shepard could not claim that the FCC was grievously wronging him by refusing to grant his chain a clear-channel license, but early on he realized what many progressive critics of radio later understood about Armstrong's system: that by offering a technological fix that obviated the FCC's hierarchal system, the new medium might democratize the broadcast industry and revive local and regional radio. Nonprofit broadcasters, largely comprising a small number of educational stations that had survived an earlier weeding-out process by the FRC, also stood to gain, because FM also allowed for more stations to be on the air.[11] FM could be, as more than one writer put it during the forties, "radio's second chance."[12]

The Yankee Network's association with FM radio began to form perhaps as early as 1935. Armstrong won Paul DeMars over straightaway—only a few weeks after the IRE demonstration—and DeMars in turn brought John Shepard into the camp. Positive results for FM followed almost immediately, as in April 1936, when DeMars helped Armstrong persuade the FCC to allocate to wideband FM an experimental portion of the radio spectrum. The commission set aside 42.5 to 43.5 megacycles and 117 to 118 megacycles, enough for ten channels (although

for technical reasons only the lower-frequency band initially proved useful for broadcasting).[13]

The importance of FM pioneers like Shepard and DeMars in accelerating the social and technological evolution of FM radio cannot be exaggerated. In 1935 only two active wideband FM stations besides the Empire State transmitter existed: Armstrong's, located in his laboratory on the campus of Columbia University, and Carman Runyon's small rig in Yonkers. By the close of 1937 Armstrong had begun to construct a 40-kilowatt station in Alpine, New Jersey, across the Hudson River from Manhattan. Shepard and DeMars were also building a 50-kilowatt station for the Yankee Network in New England, and Paul Godley planned to operate a low-wattage transmitter in New Jersey.[14] Two other early enlistees were Franklin M. Doolittle and Daniel E. Noble, both electrical engineers. (Doolittle owned AM station WDRC in Connecticut.)[15] One especially distinguished pioneer was John Hogan, the engineer of an experimental high-fidelity AM station in New York City, W2XR. A historical figure in his own right, Hogan had begun his career assisting Fessenden and de Forest thirty years earlier in their groundbreaking amplitude-modulation radiotelephony efforts. Now Hogan himself was soldiering in another revolution. In 1939, after hearing the Armstrong system, he converted W2XR into what became WQXR, the first regularly scheduled FM broadcast station in Manhattan. By 1940 dozens more had joined him, including the owners of several regional AM stations, and large radio apparatus manufacturers such as Stromberg-Carlson, General Electric, Radio Engineering Laboratories, and Westinghouse.[16]

Armstrong also stepped into the ranks of FM pioneers. In April 1936 he became an independent broadcaster, when he announced plans to build an experimental "high-power" FM transmitter, and in June the FCC approved his request to begin construction.[17] Even for a multimillionaire like Armstrong, his expenditures, made at the midpoint of the Great Depression, represented a courageous personal commitment to the future of FM broadcasting. On his application form to the FCC, he estimated the transmitter's cost at $48,000, and other apparatus at an additional $9,000.[18] Eventually, at least $250,000 went toward a transmitter building and a spectacular 400-foot tower with a trio of 150-foot crossarms.[19] But those sums covered only the down payment. Four years later Armstrong admitted that he had spent between $700,000 and $800,000 of his own funds on FM, including $300,000 for his station.[20]

Evolving toward Modern FM Radio

During the late 1930s, Armstrong and other FM pioneers continued to realize new advantages for wideband FM. First, Armstrong began to improve the overall fidelity of FM by incorporating circuits capable of reproducing sound with audio frequencies up to of 15,000 cps. He never explained how he decided on this standard, but most likely the idea grew on him as the practice of reproducing high audio frequencies became easier with experience, and as he apprehended the resulting manifest improvement in sound quality. He seems to have spread the word about this innovation much as he had about FM's static suppression properties in 1934: he told friends and staged demonstrations that showed that FM's fidelity had improved to such a level as to match Lawrence Lessing's descriptions that he incorrectly attributed to the 1935 IRE presentation. On 16 March 1938 Harry Sadenwater declared to his supervisor at RCA Manufacturing that FM now "allows the full audible range of sounds from thirty cycles to seventeen thousand cycles to be transmitted without noise or hiss in the program. And the difference in naturalness of reproduction is actually startling. I have never heard quality that would equal that demonstrated over Armstrong's apparatus."[21] Five days later the inventor showed off his newly developed high-fidelity FM system at a Radio Club of America meeting. *Broadcasting* reported that audience was "visibly impressed with the clarity and freedom from noise. The sounds of tearing paper, pouring water and ringing bells and chimes might have been coming from the … same room as far as the ears could detect."[22] In May, Armstrong presented a similar demonstration in Boston. Henry Lane, the technical editor of the *Sunday Post* called the event "the largest gathering of broadcasting and communications engineers and scientists ever to meet in Boston under the auspices of the Institute of Radio Engineers":

> Virtually spellbound, nearly 600 college professors, engineers, technicians, scientists and the curious sat for well over an hour listening to all manner of programme material, including vocal, instrumental organ, band and orchestral music, together with sounds such as tearing of paper, the pouring of water and the striking of a bell. These things were heard as they have never before been heard over a radio system. Not the least impressive feature of the new system is the practical absence of any form of background noise. Static, tube hiss, hum and the other distracting sounds that nearly always accompany conventional radio reception is entirely lacking.[23]

"The system," declared Lane, "will reproduce silence itself."[24] Such fidelity was, for all practical purposes, equivalent to what monophonic FM accomplishes rou-

tinely today. With the 15,000-cycle bandwidth now normal practice, coupled with wideband FM's already-well-known static reduction capability, FM in 1939 was the first truly low-noise, high-fidelity mass medium, setting a standard that other audio technologies, such as motion-picture sound, long-playing phonographs, and magnetic tape recording, never matched until after World War II.

In 1939 engineers at the General Electric Company announced the discovery of yet another surprising advantage over AM radio—namely, that wideband FM almost completely suppressed interstation interference. Listeners who tuned to an AM channel occupied by two stations simultaneously heard the garbled chatter of both programs combined. GE engineers had found that, by contrast, only the stronger of two FM signals was audible under comparable conditions.[25] So abruptly does an FM receiver switch from one signal to another that when a radio was installed in an automobile located at the point where the signals were approximately equal, "the movement of the car a few inches was enough to change the signal from one station to the other[,] and at practically no point were the observers able to get both signals simultaneously."[26] The implications of this news were extremely propitious for a future national broadcasting system. Now that GE had proved that interstation interference affected FM dramatically less than AM, the FCC could place FM stations much closer to each other both geographically and on the radiofrequency spectrum, accounting for a famous paradox of FM: although an individual FM channel spanned twenty times the spectrum of an individual AM channel, far more FM stations than expected could operate simultaneously without "crosstalk" in a large region. In other words, the properties of wideband FM had the potential effect of conserving spectrum generally, which hastened, as much as anything did, the FCC's acceptance of the system.

The most spectacular demonstrations during the late 1930s and 1940 proved the feasibility of wideband FM networks. In January 1938 Shepard and Armstrong announced their joint investment of half a million dollars in a network of relay stations that would allow for "catapulting . . . [radio program] signals from substantial heights" and over long distances.[27] The object of the project was to lay the foundation for a new technology of chain broadcasting, to replace Shepard's 1923 method for AM-radio networking. Under the old system, CBS and NBC leased telephone lines to transmit live broadcasts across the country from a studio, but wire lines carried no more than 4 or 5 kilocycles in audio bandwidth, only one-third of FM's capacity.[28] Shepard, DeMars, and Armstrong therefore proposed transmitting point-to-point full-channel programs from one high-altitude station to another via FM on 200-kilocycle-wide channels in the 110-megacycle band, and then broadcasting the programs locally on the 42-megacycle band.

Two years later they did so with a pair of "triple-play" relays. On 3 December 1939 and 4 January 1940—the latter date chosen because it marked the seventeenth anniversary of Shepard's chain-broadcasting idea for AM radio—Carman Runyon beamed sixty-minute programs from his home in Yonkers to Armstrong's Alpine tower. Armstrong then relayed the signal eighty-five miles to the Connecticut mountaintop antenna of W1XPW, Doolittle and Noble's experimental FM station. Finally W1XPW passed the signal on to W1XOJ, Shepard's station in Paxton, Massachusetts, which broadcast the program to metropolitan Boston.

To hear any audible speech or music after three relays would have astounded radio engineers, because even one or two comparable legs on AM distort the signal intolerably. But the quality of reception far surpassed even the most sanguine expectations. Henry Lane of the *Sunday Post* reported that "the program itself was designed to subject the system to a severe test for quietness and fidelity. Selections by piano, guitar, violin and brass instruments singly and in combination, high grade transcriptions and special sound effects served to give the listener an amazing demonstration." Lane added: "On top of this, the quality of reception in Boston with the nearest transmitter 45 miles away was fully up to a direct broadcast and showed no apparent loss of quality. Quite evidently, the process of rebroadcasting can be carried to a point far beyond that used in this initial test. The quality? You must hear it to understand how good it is. 'Natural' is the best descriptive word."[29] K. B. Warner, the longtime editor of *QST*, agreed, declaring that "it was just technically unbelievable with three relays, yet the program was still better by far than the present conventional [AM] system at its best." "In 10 years," he predicted, "there won't be any orthodox brand of broadcasting [AM radio] remaining except for the lowest grade of local service."[30]

Buoyed by this triumph, Shepard turned to the political side of FM, and on the day after the 4 January demonstration convoked in New York "73 individuals representing 49 organizations" to charter FM Broadcasters, Incorporated (FMBI), an organization dedicated to promoting wideband FM. *Broadcasting* reported that, of FMBI's members, "12 already have F-M stations: 10 have construction permits; 22 have applied for construction permits and nine propose to file such applications before . . . Feb. 28." On the founding committee sat representatives of several large regional AM stations, as well as engineers from Stromberg-Carlson, General Electric, Scott Radio, and the Radio Engineering Laboratory, a company that worked closely with Armstrong in the manufacture of FM transmitters. Even RCA and NBC sent representatives.[31]

Despite the fact that Armstrong's system had spawned a diverse community of FM pioneers, only a few squabbles impaired the harmony of the first FMBI

meeting. The most serious debate turned on the question of whether FM should be allocated a band immediately above 44 megacycles, where the FCC currently assigned television's Channel 1. Television developers understandably said no. A representative from Zenith Radio "suggested that F-M stay away from television and confine its activities to the frequencies around 100 mc." Also, Armstrong clashed with NBC's O. B. Hanson about the necessity of 200-kilocycle-wide FM channels, a standard that FM practitioners had long made permanent and that exists today. Hanson asserted that a narrower channel might suffice, and he promised that after RCA completed a series of forthcoming tests that he would provide proof—evidence that never materialized.[32]

These disputes amounted to minor distractions, though. In addressing its more important concerns, the group unanimously passed a resolution asking the FCC to begin issuing "regular," not merely experimental, licenses to frequency modulation stations; to increase the number of FM channels from five to fifteen; and to locate the future FM band near the current one of 42.5–43.5 megacycles, preferably from 41 to 44 megacycles.[33] Indeed, Shepard had already paved the way for these proposals. In October he had petitioned the FCC for a hearing to grant the Yankee chain "a regular license as distinguished from an experimental license." This amounted to a call for the FCC to issue commercial licenses on a routine basis, because restricting the privilege to a single station would make little sense. In early December, E. K. Jett, the FCC's chief engineer, met with Armstrong and subsequently ordered a "study which will compare F-M potentialities with amplitude modulation."[34] Finally, on 19 December the FCC announced that Yankee would get its hearing.[35] After polling dozens of FMBI members and other interested parties, the panel scheduled a date: 18 March 1940.

RCA and FM Radio during the Late 1930s

The presence of RCA representatives at FMBI's inaugural meeting raises the question of what RCA had done with frequency modulation since passing on the Armstrong system four years earlier. The answer is, even to be kind, not much, aside from articles about phase and frequency modulation that Murray Crosby had published in the *Proceedings of the Institute of Radio Engineers* and the *RCA Review*.[36] Tellingly, RCA acquired the rights to no FM patents during the years 1937, 1938, and 1939, precisely when Armstrong and others were hammering out the specifications of modern broadcast FM radio.

One sign that Armstrong intended to isolate RCA from FM was his expensive decision in 1937 to ask General Electric, not RCA, to build the first batch of FM

tabletop receivers. In May, GE quoted $900 for one set, but Armstrong negotiated a lower unit price by agreeing to buy twenty-five units at around $400 each.[37] (He would typically present these receivers to FCC commissioners, members of Congress, and other individuals with the power to influence FM's future.) Contracting General Electric to assemble a few FM receivers proved costly, but he could not abide doing business with RCA, which might have built cheaper sets. When Harry Sadenwater inquired "why [RCA Manufacturing] had not been given an opportunity to make these receivers," Armstrong replied, according to Sadenwater, "Because the RCA Patent Attorneys were trying to steal [my] invention."[38]

In fact, most activity within the company centered not at all on thievery but rather on a pointless, mostly after-the-fact debate about FM's commercial feasibility. Determined doubters like Ralph Beal at first felt no qualms about letting Armstrong's system go, chiefly because they simply questioned whether frequency modulation could reduce static noise, resolutely holding to the conviction that wideband FM's lack of static resulted only from the fact that the system operated in the ultra-high frequencies. Armstrong's claims for FM, Beal still insisted at the end of 1937, amounted only to "coupl[ing] with his modulation method the advantages of freedom from atmospheric disturbances and ability to obtain better quality by the use of a greater channel width." "Both of these advantages," explained Beal, "are common to any ultra short wave station regardless of the modulation method employed."[39]

Supporters of Armstrong FM within RCA—all engineers, and none of them senior managers—comprised a tiny, often cautious faction. Clarence Hansell, for instance, wished Armstrong success with the station he proposed to build in Alpine: "I have been trying to find an opportunity for a number of years to get frequency modulation transmission into commercial service." He cordially promised that he "will be watching with considerable interest your efforts to establish a frequency modulation broadcast transmitter."[40] Harold Beverage also believed in wideband FM, but he had all but given up on any fight to bring RCA around.

In contrast to Beverage and Hansell, who despaired of recapturing RCA's lead in the FM race, Harry Sadenwater stalwartly advocated frequency modulation—more than anyone else in the organization did. Although only a rank-and-file engineer, Sadenwater bravely took to scolding his superiors in the company for neglecting wideband FM. Predicting "approximately 1,000 50 kw. [FM] stations" in the near future, he recommended to a vice president in early 1936 that "our advanced development group begin to outline commercial [FM] apparatus to meet possible inquiries from our customers."[41] Two years later, upon learning that NBC proposed to spend $8,500 on an experimental high-fidelity stereo

amplitude-modulation radio experiment, Sadenwater barely contained his outrage as he explained that FM had already produced high-fidelity and ultra-high-frequency broadcasts. "From almost every technical viewpoint that I can visualize, the ultra-high frequency broadcasting that is developing will undoubtedly finally utilize frequency modulation," he asserted. Rather than squander money on high-fidelity AM radio, Sadenwater stated, "we should be prepared to supply frequency modulation equipment."[42]

On 16 March 1938, soon after receiving his first pay raise in almost a decade, Sadenwater dispatched an especially pointed memorandum to C. K. Throckmorton, the executive vice president of RCAM. The letter conveyed the tone of an aging ("grown gray," as Sadenwater described himself) company man who had paid his dues and now demanded to be heard. He recounted how he had operated an amateur station in 1908, "when antennas were far and few between." He "taught radio school in N.Y.C." from 1914 to 1917, and as a lieutenant (junior grade) had served as radio officer on NC-1, one of the group of four navy flying boats that attempted to cross the Atlantic in 1919 (Sadenwater's craft made a forced landing short of the Azores, but one of the other airplanes completed the trip). As a field engineer for General Electric during the twenties, he built several high-power broadcast stations before transferring to RCA in 1930.[43]

In Sadenwater's opinion, RCA had fumbled FM, "the most important subject for any of us in the radio manufacturing business." "Frankly," he admitted, "I've been a bit discouraged because it's been a long, long time since any increase in salary has come my way. . . . But because I have faith in radio and the fundamentally sound need for RCA I have repeatedly determined to stick to the ship." Sadenwater led Throckmorton point-by-point through the case for Armstrong's system. Allowing that AM receivers had saturated the consumer market, he nonetheless insisted that the public would buy more radios if RCA were to offer "something new and appreciably better." He declared that "the sounds made by [AM] broadcast receivers and motion picture reproducing systems are horribly distorted. It really makes me irritable and nervous to listen to them." He stated that "good fidelity in the existing [AM] broadcast band is impossible due to the large number of stations and the few channels available." "From every angle that I have looked at the new [wideband FM] system, my conclusion has been favorable to it and I am sure it will ultimately be the system used for broadcasting."[44]

Sadenwater blamed some of the most powerful men in RCA for the firm's mistakes. "I have discussed this matter with our engineers," he told Throckmorton, "and Mr. Clement [an RCAM vice president] seems to be positive in his conclusion that it is of no importance. I can only believe that he does not know enough

about it and that the reports on which he had based his conclusions were not well founded on good data and on enough experience." Sadenwater questioned the judgment of one engineer-manager in particular, a man who had participated in KDKA's FM experiments of the 1920s. "I have also many times discussed this matter with C. W. Horn, the Development Engineer of the N.B.C. Horn says it is impractical to hope to replace the great quantity of receivers now in the hands of the public, representing an investment of several billion of dollars. My answer is that it has been done, gradually, twice before and will be done again. Horn also questions the practicality of discontinuing the present broadcast service being rendered by [AM] stations. . . . As I see it, it could be worked out with time."[45]

As an overt champion of FM, Sadenwater stood virtually alone in RCA until the end of 1938, when he obtained an ally in Dale Pollack, a fellow RCAM engineer and a recent graduate of the Massachusetts Institute of Technology. Initially, Pollack numbered among the skeptics. In late 1937, he had gingerly suggested that RCA merely keep a hand in frequency modulation. Predicting "considerable application of frequency modulation in the near future," he recommended only "a new method of frequency modulation, simpler than Armstrong's."[46] Fourteen months later, though, Pollack began to agree with Sadenwater, after hearing a talk that W. R. G. Baker, the manager of General Electric's Radio and Television Department, gave on FM at an IRE meeting in Rochester. Indeed, Baker himself had recently converted from skeptic to crusader in the army of FM pioneers. From 1929 to 1935 he had been the production manager of RCAM, where he consistently weighed in against the development of frequency modulation.[47] Since joining General Electric, however, he had shifted to the other side of the issue and, with the conviction of a repentant sinner, was earning a reputation as the driving force behind GE's support of Armstrong FM. Pollack reported to his superiors that "from the tenor of [Baker's] introductory and closing remarks it was evident that the advantages of frequency modulation are fully appreciated by General Electric. . . . Some of Baker's remarks on this point were quite emphatic." Pollack concluded that "the principal thing impressed upon me . . . is that a great deal of work has already been done [by RCA's competitors] on frequency modulation. . . . If we are not to be left behind our development should be accelerated."[48]

Pollack urged that RCA rectify "three broad problems . . . if we are to learn to design frequency modulated transmitters": the firm's lack of "practical circuits for producing frequency modulation"; the need to design measuring equipment to assess the performance of the not-yet-designed transmitters and receivers; and, finally, an institutional ignorance in the field of frequency-modulation theory.[49] RCA, once the cynosure of FM research and development, had lost, in Pollack's

opinion, almost all the often-tacit knowledge necessary to design practical apparatus. Aside from Murray Crosby's important theoretical work, Pollack was right. RCA had done almost nothing with FM since letting the Armstrong system slip its grasp and had almost forgotten what it learned during the previous decade of research. The firm that prided itself as leading the vanguard in telecommunications research could barely manage to bring up the rear of FM development.

Conservatives who opposed the development of FM eventually realized their error, however slowly—but not because of the technical reasons that Sadenwater and Pollack had pointed out. The widely publicized achievements of such FM pioneers as Shepard, DeMars, and Armstrong himself carried far more weight. In late 1938, after a flurry of press releases and articles lauding FM issued from the popular, engineering, and broadcast industry press, Ralph Beal scheduled a staff meeting for 20 January 1939, two weeks after Armstrong and Shepard's second mountaintop relay demonstration and the FMBI's first meeting, "to consider the subject."[50] Dale Pollack (but not Harry Sadenwater) sat in, and afterward Pollack wrote his bluntest criticism of RCA's policy. Because RCA lagged so far behind, he insisted, its engineers should organize "an intensive development program with as little delay as possible." Pollack added that he had reviewed the Empire State Building FM test reports of 1934–35 and had made a disturbing discovery—namely, that the trials had been so badly planned and carried out as to render their results worthless. He included among the dozen flaws he listed that "many more listeners under a wider variety of circumstances should have been used, and more measurements should have been made. Only one listener at a given location was used and the period covered, two to seven days at each location, was too short." He also cited the low transmitter power used at the time—only 2 kilowatts, in contrast to the 40 and 50 kilowatts that Armstrong and Shepard were now using successfully.[51] Again, Pollack was right; moreover, the early tests evaluated FM performance chiefly at the periphery of its radiation pattern, which effectively guaranteed erratic reception.

Even when RCA managers began, in late 1939, to accept the reality of wideband FM, an institutional arrogance about the Armstrong system retarded their transformation. Some employees believed that FM, even at this late date, could not survive economically without RCA's backing. Clarence Hansell, for example, told Niles Trammel, the new president of NBC, that "the Major and other investigators cannot put frequency modulation over on a commercial basis in broadcasting unless a company like RCA, controlling a manufacturing company and a broadcasting chain, sponsors it."[52] O. B. Hanson also brushed aside the FM pioneers, who, he believed, foolishly presumed to displace RCA from its role as a

telecommunications leader. "It is doubtful," he stated in a memorandum written four days after Beal's meeting, "if individual investigators who are now building frequency modulation transmitters can, by themselves, swing the industry in that direction." He continued: "Whatever system [of FM] is adopted by RCA, its manufacturing company and its broadcasting company, will probably be the governing factors in the future."[53] The same assumptions underlay Hanson's proposal, at the inaugural meeting of FMBI a year later, to adopt a standard channel width narrower than 200 kilocycles per second. Incredibly, he made this suggestion despite the fact that RCA engineers had logged almost no practical experience with FM technology for half a decade.

This smugness arose in large part from a universal belief within the company that FM posed no economic threat to RCA. In early 1939, Hanson explained that whatever he disliked about frequency modulation, he did not fear the injury the new system might inflict on RCA's investment in AM radio. "Regardless of what technical system is used," he assured the president of NBC, "the expansion of broadcasting in the ultra short wave field will have its effect on our company by the dilution of the listening market. This, in itself, is not too serious in my opinion, as in the last analysis it is the program material that gets the listeners."[54] In other words, the profitability of RCA, through its subsidiary company NBC, rested more on whether listeners tuned into the network's radio programs than on the kind of technology that carried those programs.

RCA's managers did, to be sure, eventually come to exhibit nervousness about FM, but only after realizing that their proud company might fall even further behind its competitors, especially Westinghouse, Stromberg-Carlson, Zenith, and General Electric. Armstrong had already licensed at least nine companies that attended FMBI's first meeting to use his patents to manufacture FM receivers.[55] "All indications," warned one RCA manager in May, 1939, "are that [General Electric and Westinghouse] are going to promote frequency modulation, and their activities, together with those of the REL, are making it daily more embarrassing for us and I therefore feel that we must get ourselves in a position to be able to furnish quotations to broadcasters on frequency modulation transmitters and receivers."[56] "CBS," Clarence Hansell informed Niles Trammel, "is filing [an application with the FCC] for a channel for frequency modulation. We should do the same."[57] Trammel's response exemplified how much apathy—an apathy anchored in ignorance and complacence—still pervaded the feelings of NBC's managers about FM: "I hope you keep me advised of the developments as they occur. . . . Should CBS engage in frequency modulation, how much of an advantage will it give them over us?"[58]

By the spring of 1939, RCA had sloughed off a few layers of this indifference, with several managers acknowledging that FM pioneers had transformed a technology that once seemed of dubious value into one that now appeared inevitable. Ralph Beal signed off on an engineering report that recommended "the adoption and use of frequency modulation for the transmission of sound in all domestic broadcasting services which use ultra short waves." But the company's managers were also determined to leave RCA's stamp on the medium before the FCC "black-boxed" it—that is, before the commission established permanent technical standards. Although every FM practitioner outside RCA had accepted Armstrong's 150-kilocycle swing as normal practice for more than six years, the Beal report declared that "no conclusion was reached [by RCA engineers] as to the amount of deviation or frequency swing to be suggested."[59]

Another indication of RCA's inability to grasp its FM problem was that, because of the firm's paltry recent experience with frequency modulation, company engineers could not build practical, commercial-quality, apparatus. In June 1939, R. D. Duncan Jr. of RCA Manufacturing's Transmitter Development Section admitted that "sentiment in RCAM is somewhat divided [about FM], not as to the apparent technical advantages, but as to the advisability of its full adoption without further engineering, manufacturing and operating experience."[60] O. B. Hanson discovered that the entire RCA organization could provide no more than a couple of obsolete receivers. With some embarrassment, he therefore placed an order with two competitors, General Electric and Radio Engineering Laboratories, for seven FM sets, one of which was to be installed in the home of NBC's president, Lenox Lohr. In September the FCC approved NBC's application to construct a diminutive 1-kilowatt FM station in the Empire State Building.[61] Oddly, Hanson justified the expense, $12,000, as an opportunity to refute the claim that FM suppressed static. He pointed out at the time that "no real comparative tests have been made between frequency modulation and amplitude modulation on the same wave length."[62] This statement showed once more how Hanson and other RCA managers had completely lost touch with the still-evolving theory and normal practice of FM. In fact, FM pioneers had produced mountains of evidence, much of it published, that the Armstrong system suppressed static. Moreover, despite ample publicity about frequency modulation, Hanson mentioned none of the several other features that attracted broadcasters to FM, such as high fidelity and minimal interstation interference. At the moment of birth of the first commercial FM radio service in 1940, RCA had almost nothing to do with the delivery.

"Almost a Cakewalk": The FCC Creates Commercial FM

Within a year, FM radio would become a permanent fixture in American broadcasting, with RCA having almost nothing to say about the matter. On the morning of 18 March 1940, the FCC hearing to create a commercial FM broadcast service that John Shepard and FMBI had sought since October convened. Chairman James Lawrence Fly rapped his gavel to open what he declared as FM's "day in court," the largest assembly before the commission in its five-year history. Fly had to borrow a three-hundred-seat auditorium from the Interstate Commerce Commission, and one hundred people still had to listen to the proceedings from loudspeakers mounted outside.

To those who attended the two-week-long hearing, the greatest surprise was a lack of rancor. Twenty-nine organizations had asked to send representatives to testify, and reporters who had been covering wideband FM predicted that the hearing would continue Armstrong's "fight" or "battle" with RCA on behalf of his invention.[63] At the start of the hearing, the *New York Times* described the radio industry as "sharply divided" over FM, and *Broadcasting* noted that a "substantial portion" of the four hundred audience members "viewed FM as a prospective Frankenstein that might turn on their established station operations and introduce new competition of a character that might prove ruinous."[64] But after these skeptics heard FMBI witnesses forecast a transition period of "roughly 10 years," "this viewpoint appeared to subside."[65] Moreover, signs soon appeared that the commission would reach a favorable conclusion for the FM pioneers. When Armstrong, the first witness, played recordings inscribed on motion-picture film of AM and FM reception in Haddonfield that RCA had made in 1935, *Electronics* stated that "the advantage in favor of f-m was so marked, and the static so prominent on the a-m portions of the film that Chairman Fly asked that the final record be turned off before its conclusion, granting the demonstration as conclusive." Armstrong commanded such a strong position that he could easily afford to be unusually conciliatory, admitting that FM's lower static levels were partly "due to the use of the higher frequencies, inasmuch as natural static decreases roughly in proportion to the increase in frequency." But he also insisted that FM excelled at discriminating against man-made noises, an assertion that no one challenged.[66]

Several observers expected far more wrangling during the second week, and *Electronics* confidently promised "stiff opposition on the part of RCA." But Frank W. Wozencraft, RCA's chief counsel, urged the FCC to give regular FM service the "green light," thus "taking FM proponents wholly by surprise," reported *Broadcasting*.[67] Wozencraft made only two requests. First, he asked the commission

to give a television channel other than No. 1 to FM, "since that channel is now in regular use." He also repeated RCA's suggestion that FM channels narrower than 200 kilocycles per second might suffice for practical purposes, although he undercut his position by conceding that a wider channel had a better signal-to-noise ratio.[68] Both of these ideas attracted almost no support. "If there is any real opposition to FM as a new commercial service to supplement rather than supplant the present standard broadcast structure employing amplitude modulation," Sol Taishoff, the editor of *Broadcasting*, declared, "it was not evident during the proceedings." And if any debate occurred, the FCC almost always ruled in favor of FMBI. "What was expected to be a battle royal between opponents and proponents of wide-band FM," Taishoff observed, "turned out to be almost a cakewalk for the disciples of Maj. Edwin H. Armstrong."[69]

In fact, FM's "trial" more closely resembled a two-week colloquium, as the commissioners interviewed one expert witness after another about technical specifications. This was understandable, given that the FCC would be the first agency to regulate the new medium. The panel's sharpest questions challenged the necessity of a 15,000-cycle audio bandwidth. Chief Engineer Jett asked Armstrong whether 10,000 or 11,000 might suffice, to which Armstrong responded that 15,000 cycles gives the greatest "naturalness" to reception. Commissioner T. A. M. Craven, Jett's predecessor, as chief engineer, asked the inventor much the same thing, perhaps seeking a way to narrow the Armstrong system's 200-kilocycle channel width. Armstrong essentially answered that reducing the audio bandwidth would have almost no effect on the channel width, an explanation that ended Craven's questions. At no time did any commissioner contradict the technical judgment of Armstrong or any other advocate of his system.[70]

Of course, the FCC's subsequent decisions were anticlimactic. On 20 May 1940 the panel established the commercial service that FMBI wanted on a band of spectrum from 42 to 50 megacycles, enough for forty channels. The lowest five, from 42 to 43 megacycles, were reserved for "educational stations on a regular broadcast basis," establishing a precedent for the 4 megacycles of noncommercial broadcasting on today's FM band.[71] The 200-kilocycle channel was retained, and television Channel 1, which had occupied 44 to 50 megacycles, was eliminated. The panel adopted none of RCA's proposals. During the past nearly seven decades, broadcast FM radio has continued to evolve; the FCC shifted the FM band to its present location in 1945, for instance, and in 1961 the commission authorized a method to broadcast stereophonic sound. But the FCC has never failed to preserve the essential standards of the technology, which Armstrong and other FM pioneers worked out during the late 1930s.