



PROJECT MUSE®

Early FM Radio

Frost, Gary L.

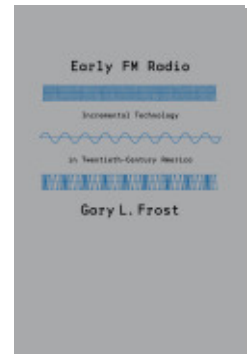
Published by Johns Hopkins University Press

Frost, L.

Early FM Radio: Incremental Technology in Twentieth-Century America.

Baltimore: Johns Hopkins University Press, 2010.

Project MUSE., <https://muse.jhu.edu/>.



➔ For additional information about this book

<https://muse.jhu.edu/book/470>

Access provided at 26 May 2019 01:08 GMT with no institutional affiliation



This work is licensed under a Creative Commons Attribution 4.0 International License.

Introduction • What Do We Know about FM Radio?

Epigraph. Congress, Senate, Committee on Interstate Commerce, *A Bill to Amend the Communications Act of 1934, and for Other Purposes*, 78th Cong., 1st sess., 3 Nov.–16 Dec. 1943, 679.

1. Ken Burns, Geoffrey C. Ward, and Tom Lewis, *Empire of the Air: The Men Who Made Radio*, film directed by Ken Burns (Los Angeles, Calif.: Pacific Arts Video, 1992); Lawrence P. Lessing, *Man of High Fidelity: Edwin Howard Armstrong* (Philadelphia: J. B. Lippincott, 1956); *Man of High Fidelity: Edwin Howard Armstrong*, 2d ed., with new foreword and final chapter (New York: Bantam Books, 1969). Unless otherwise noted, all page citations are from the 1956 edition.

2. See Donald MacKenzie and Judy Wajcman, eds., *The Social Shaping of Technology*, 2d ed. (Buckingham: Open University Press, 1999); Wiebe E. Bijker, Thomas Parke Hughes, and Trevor J. Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, Mass.: MIT Press, 1987); Angela Lakwete, *Inventing the Cotton Gin: Machine and Myth in Antebellum America* (Baltimore: Johns Hopkins University Press, 2003); David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (New York: Oxford University Press, 1977); Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, Mass.: MIT Press, 1994); Nathan Rosenberg, *Inside the Black Box: Technology and Economics* (Cambridge: Cambridge University Press, 1982). The argument for incremental technological change is at least several decades old. See S. Colum Gilfillan, *The Sociology of Invention* (Chicago: Folliett, 1935; repr., Cambridge, Mass.: MIT Press, 1970); George Basalla, *The Evolution of Technology* (New York: Cambridge University Press, 1988).

3. This study combines the categories of phase modulation and frequency modulation. The differences between the two are trivial for the purposes of this study.

4. In 1960 the Conférence générale des poids et mesures defined the Hertz as the new unit of measurement for frequency, but here I use cycles per second (cps) to conform to the great majority of sources used in this study.

5. It should be noted that, strictly speaking, the concept of “instantaneous frequency” is mathematically and practically problematic when the frequency is changing. I use the concept only to sketch out the basics of frequency-modulation theory for the layperson.

6. Lessing, *Man of High Fidelity*, 293.

7. *Ibid.*, 308.

8. *Ibid.*, 258.

9. *Ibid.*, 226, 309.

10. *Ibid.*, 309, 234, 240, 296, 299.

11. *Ibid.*, 11. The foreword to the 1969 edition of *Man of High Fidelity*, ix, makes a stronger claim, offering a historical, legal, and personal “vindication” of FM radio.

12. Hugh Slotten disputes the traditional claim that in 1945 the FCC transferred the commercial broadcast FM service from 42–50 megacycles to 88–108 megacycles out of a motivation to “cripple” FM. Hugh Richard Slotten, “‘Rainbow in the Sky’: FM Radio, Technical Superiority, and Regulatory Decision-Making, 1936–1948,” in *Radio and Television Regulation: Broadcast Technology in the United States, 1920–1960* (Baltimore: Johns Hopkins University Press, 2000), 113–44.

13. The other book that focuses on the history of FM radio is Don V. Erickson, *Armstrong’s Fight for FM Broadcasting: One Man vs. Big Business and Bureaucracy* (University: University of Alabama Press, 1973). See also Charles A. Siepmann, *Radio’s Second Chance* (Boston: Atlantic-Little, Brown Books, 1946); W. Rupert Maclaurin, *Invention and Innovation in the Radio Industry* (New York: Macmillan, 1949), 183–90, 228–31; Christopher H. Sterling, “Second Service: Some Keys to the Development of FM Broadcasting,” *Journal of Broadcasting* 15 (Spring 1971): 181–94; Lawrence Lessig, *Free Culture: How Big Media Uses Technology and Law to Lock Down Culture and Control Creativity* (New York: Penguin, 2004), 3–6. Almost all Web pages that recount the history of FM radio cite Lessig and often Erikson. See, for example, Jorge Amador, “Edwin Armstrong: Genius of FM Radio” (Apr. 1990), www.thefreemanonline.org/columns/edwin-armstrong-genius-of-fm-radio/, Web page of the Foundation for Economic Education, viewed 1 Apr. 2009. One Web-based history of FM radio seems to embellish Lessig, but cites no sources. “Edwin Howard Armstrong: The Creator of FM Radio,” Web page of the First Electronic Church of America, <http://fecha.org/armstrong.htm>, viewed 1 Apr. 2009.

14. Thomas Parke Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm* (New York: Viking Press, 1989); Tom Lewis, *Empire of the Air: The Men Who Made Radio* (New York: Edward Burlingame Books, 1991). Lewis’s book was made in collaboration with Ken Burns. See Burns, Ward, and Lewis, *Empire of the Air*; Susan J. Douglas, “The FM Revolution,” in *Listening In: Radio and the American Imagination, from Amos ’n’ Andy and Edward R. Murrow to Wolfman Jack and Howard Stern* (New York: Times Books, 1999), 256–83. Douglas suggests the possibility of an alternative to “Armstrong’s conspiracy theory” (262, n. 14).

15. Christopher H. Sterling and Michael C. Keith, *Sounds of Change: A History of FM Broadcasting in America* (Chapel Hill: University of North Carolina Press, 2008).

16. John M. Staudenmaier, “Recent Trends in the History of Technology,” *American Historical Review* 95 (June 1990): 715–25; and *Technology’s Storytellers: Reweaving the Human Fabric* (Cambridge, Mass.: MIT Press, 1985).

17. Smith and Marx, introduction to *Does Technology Drive History?*, ix–xv.

18. Thomas Parke Hughes, “The Seamless Web: Technology, Science, Etcetera, Etcetera,” *Social Studies of Science* 16 (May 1986): 281–92.

19. Donald MacKenzie and Judy Wajcman, “Introductory Essay: The Social Shaping of Technology,” in MacKenzie and Wajcman, *The Social Shaping of Technology*, 3–27.

20. Nathan Rosenberg, “Technological Interdependence in the American Economy,” *Technology and Culture* 20 (Jan. 1979): 25; reprinted in Rosenberg, *Inside the Black Box*, 55.

21. Susan J. Douglas, “Popular Culture and Populist Technology: The Amateur Operators, 1906–1912,” in *Inventing American Broadcasting, 1899–1922* (Baltimore: Johns Hopkins University Press, 1987), 187–215.

Chapter One • AM and FM Radio before 1920

Epigraph. Valdemar Poulsen, “A Method of Producing Undamped Electric Oscillations and Its Employment in Wireless Telegraphy,” *Electrician* 58 (16 Nov. 1906): 166–68. The author thanks Hans Buhl for providing copies of several articles related to the Poulsen arc, and for pointing out that Poulsen opposed the very method he invented. Emails to author 18–20 July 2001. For an English-language summary of Dr. Buhl’s Ph.D. dissertation, see “The Arc Transmitter—A Comparative Study of the Invention, Development and Innovation of the Poulsen System in Denmark, England and the United States,” Web page of the Steno Museum for the History of Science and Medicine, University of Aarhus, www.stenomuseet.dk/person/hb.ukref.htm, viewed 1 Apr. 2009.

1. Hugh G. J. Aitken, *Syntony and Spark: The Origins of Radio* (Princeton: Princeton University Press, 1976); Sungook Hong, *Wireless: From Marconi’s Black Box to the Audion* (Cambridge, Mass.: MIT Press, 2001), 19.

2. Edward W. Constant II, *The Origins of the Turbojet Revolution* (Baltimore: Johns Hopkins University Press, 1980); Thomas Parke Hughes, *Networks of Power: Electrification in Western Society, 1850–1930* (Baltimore: Johns Hopkins University Press, 1983), esp. 15–16.

3. Reginald Aubrey Fessenden, “Wireless Telephony,” *Proceedings of the Institute of Electrical Engineers* 27 (29 June 1908): 1283–1358.

4. Hong, *Wireless*, 96 (emphasis in original).

5. Cornelius D. Ehret, “Art of Transmitting Intelligence,” U.S. Patent No. 785,803, application date: 10 Feb. 1902, issue date: 28 Mar. 1905; and, “System of Transmitting Intelligence,” U.S. Patent No. 785,804, application date: 10 Feb. 1902, issue date: 28 Mar. 1905.

6. Valdemar Poulsen, “Fremgangsmaade til Frembringelse af Vekselstrømme med højt Svingsningstal” (Method for Generating Alternating Current with High Frequencies), Danish Patent No. 5,590, application date: 9 Sept. 1902, issue date: 3 Apr. 1903.

7. Raymond F. Guy, “F-M and U-H-F,” *Communications* 28 (Aug. 1943): 30; Ehret is also mentioned in a footnote in Christopher H. Sterling, “Second Service: Some Keys to the Development of FM Broadcasting,” *Journal of Broadcasting* 15 (Spring 1971): 181–94. Sterling and Keith also discuss Ehret in their 2008 book. Christopher H. Sterling and Michael C. Keith, *Sounds of Change: A History of FM Broadcasting in America* (Chapel Hill: University of North Carolina Press, 2008).

8. *Armstrong v. Emerson Radio and Phonograph Corporation*, 179 F. Supp. 95, Southern District of New York, 1959.

9. Eugene S. Ferguson, “The Tools of Visualization,” in *Engineering and the Mind’s Eye* (Cambridge, Mass.: MIT Press, 1992), 75–113.
10. Ehret, U.S. Patent Nos. 785,803, 785,804.
11. See, for example, Frederick Emmon Terman, *Radio Engineering* (New York: McGraw-Hill, 1937), 587.
12. For an early example of a limiter circuit, see Pierre Mertz, “Electrical Transmission of Pictures,” U.S. Patent No. 1,548,895, application date: 26 Jan. 1923, issue date: 11 Aug. 1925. This patent describes a wired frequency-modulation picture transmission system.
13. Poulsen, Danish Patent No. 5,590. In June 1903 Poulsen applied for an American patent for the same invention. Valdemar Poulsen, “Method of Producing Alternating Currents with a High Number of Vibrations,” U.S. Patent No. 789,449, application date: 19 June 1903, issue date: 9 May 1905.
14. Aitken shows three photographs of three such alternators, all rated at 200 kilowatts output. Hugh G. J. Aitken, *Continuous Wave: Technology and American Radio, 1900–1932* (Princeton: Princeton University Press, 1985), 313, 324, and 423.
15. Hong, *Wireless*, 164.
16. Poulsen, “A Method of Producing Undamped Electric Oscillations.”
17. *Ibid.*, 167.
18. “Poulsen Wireless Station at Lyngby,” *Modern Electrics* 1 (June 1908): 81. This article states that “good operators can work with less than 1% difference of the wave length.”
19. Poulsen, “A Method of Producing Undamped Electric Oscillations,” 167.
20. Cyril F. Elwell, “The Poulsen System of Wireless Telephony and Telegraphy,” *Journal of Electricity, Power and Gas* 24 (2 Apr. 1910): 293–97, quotation on p. 294.
21. Lee de Forest, “Recent Developments in the Work of the Federal Telegraph Company,” *PIRE* 1 (Mar. 1913): 37–57, quotation on p. 39.
22. Elihu Thomson, “Method and Means for Producing Alternating Currents,” U.S. Patent No. 500,630, application date: 18 July 1892, issue date: 4 July 1893.
23. John Grant, “Experiments and Results in Wireless Telephony,” *American Telephone Journal* 15 (26 Jan. 1907): 49; Fessenden, “Wireless Telephony.”
24. Elmer E. Bucher, *Practical Wireless Telegraphy: A Complete Text Book for Students of Radio Communication*, rev. ed. (New York: Wireless Press, 1921), 267.
25. Reginald Aubrey Fessenden, “Apparatus for Signaling by Electromagnetic Waves,” U.S. Patent No. 706,747, application date: 28 Sept. 1901, issue date: 12 Aug. 1902.
26. Gary L. Frost, “The Two Careers of Reginald Aubrey Fessenden” (Master’s thesis, University of North Carolina–Chapel Hill, 1993).
27. Alexander Nyman, “Combined Wireless Sending and Receiving System,” U.S. Patent No. 1,615,645, application date: 15 July 1920, issue date: 25 Jan. 1927. Technically, Albert Day beat Nyman by more than a year, filing for his phase-modulation invention in early 1919. But the thirteen years separating Day’s filing and issue dates suggest that the final document differed considerably from the original application. Albert V. T. Day, “Method and Means for Electrical Signaling and Control,” U.S. Patent No. 1,885,009, application date: 25 Jan. 1919, issue date: 25 Oct. 1932.

28. Murray G. Crosby, “Notes on FM Lecture by Major Armstrong given in the A.I.E.E. sponsored course in frequency modulation on Oct. 14, 1940,” 16 Oct. 1940, box 183, AP.

29. The number of female amateur radio operators has never been determined. I have discovered no women practitioners who worked directly with FM radio technology before World War II.

30. Greenleaf Whittier Pickard, “Means for Receiving Intelligence by Communicated by Electric Waves,” U.S. Patent No. 836,531, application date: 30 Aug. 1906, issue date: 20 Nov. 1906; Henry C. Dunwoody, “Wireless-Telegraph System,” U.S. Patent No. 837,616, application date: 23 Mar. 1906, issue date: 4 Dec. 1906.

31. Susan J. Douglas, “Popular Culture and Populist Technology: The Amateur Operators, 1906–1912,” in *Inventing American Broadcasting, 1899–1922* (Baltimore: Johns Hopkins University Press, 1987), 188–215.

32. *Ibid.* For an examination of masculinity and amateur radio in post–World War I America, see Kristin Haring, *Ham Radio’s Technical Culture* (Cambridge, Mass.: MIT Press, 2006).

33. “The Wireless Club,” *Electrician and Mechanic* 19 (Sept. 1908): 137.

34. Hugo Gernsback, “Wireless and the Amateur: A Retrospect,” *Modern Electrics* 4 (Feb. 1913): 1143.

35. Robert A. Morton, “The Amateur Wireless Operator,” *Outlook* 94 (15 Jan. 1910): 131.

36. “The Radio League of America: A Retrospect,” *Electrical Experimenter* 3 (Dec. 1915): 381.

37. Harold H. Beverage and Harold O. Peterson, Electrical Engineers, an oral history conducted in 1968 and 1973 by Norval Dwyer, IEEE History Center, Rutgers University, New Brunswick, N.J.

38. *Ibid.* “DX” referred to the practice of listening to distant radio stations.

39. Radio Club of America, “A History of the Radio Club of America,” Radio Club of America Web page, www.radio-club-of-america.org/history.php, viewed 1 Apr. 2009, adapted from George E. Burghard, *The Twenty-Fifth Anniversary Year Book* (New York: Radio Club of America, 1934).

40. W. E. D. Stokes Jr. remained an amateur and a member of the Radio Club of America. In 1989 he suffered a stroke, and he died on 10 March 1992, when he was ninety-six years old. Houston Stokes, telephone interview by Gary L. Frost, 27 Feb. 2002.

41. “The First Amateur Radio Club in America,” *Radio Broadcast* 2 (Jan. 1923): 222.

42. *Ibid.* See “Godley to England to Copy Transatlantics,” *QST* 5 (Oct. 1921): 29; George E. Burghard, “Eighteen Years of Amateur Radio,” *Radio Broadcast* 2 (Aug. 1923): 290.

43. Gernsback, “Wireless and the Amateur,” 1143.

44. *Ibid.*

45. “Boy Amateur, Assailing Wireless Bill, Predicts an ‘Air Trust,’” *New York Herald*, 29 Apr. 1910.

46. Radio Club of America, "History of the Radio Club of America."
47. "First Amateur Radio Club in America," 222.
48. Burghard, "A History of the Radio Club of America."
49. Paul F. Godley, "Prof. Armstrong's System—What It Means: Frequency Modulation Plan Furnishes Plenty of Food for Thought on Future of the Broadcast Industry," *BBA* 11 (1 July 1936): 72. Burghard was the club's president in 1923. See "Radio Device Ending Fading, Static Reported: Armstrong Perfects Method Increasing Range of Ultra-Short Wave Broadcasting," *New York Herald Tribune*, 26 Apr. 1935.
50. Armstrong thanked Styles, Shaughnessy, Burghard, and Runyon for their help in his seminal paper on FM radio. Edwin Howard Armstrong, "A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation," *PIRE* 24 (May 1936): 689–740.

Chapter Two • Congestion and Frequency-Modulation Research, 1913–1933

Epigraphs. Lose M. Ezzy [pseud.], "I'm Forever Losing Signals," *QST* 4 (Sept. 1920): 43. H. P. Davis to David Sarnoff, 11 Mar. 1931, box 275, microfilm reel, "RCA-1 C.S. & M: #1 to #1419," frame 595, AP.

1. Erik Barnouw, *A Tower in Babel: A History of Broadcasting in the United States to 1933* (New York: Oxford University Press, 1966; repr. 1978). For a detailed history of congestion, see Marvin R. Bensman, *The Beginning of Broadcast Regulation in the Twentieth Century* (Jefferson, N.C.: McFarland, 2000).

2. Gleason L. Archer, *History of Radio to 1926* (New York: American Historical Society, 1938), 393–97.

3. Hugh G. J. Aitken, "Allocating the Spectrum: The Origin of Radio Regulation," *Technology and Culture* 35 (Oct. 1994): 686–716; Bensman, *Broadcast Regulation*, 84.

4. Bensman, *Broadcast Regulation*, 84.

5. Benjamin Gross, "How to Demonstrate F-M: Details of Public Demonstration at R. H. White Department Store, with Complete Radio Script of Program Transmitted by W1XOJ," *FM* 1 (Nov. 1940): 16.

6. *Radio Act of 1912*, Pub. L. 62-264, 13 Aug. 1912, sec. 4.

7. Sungook Hong, "Hertzian Optics and Wireless Telegraphy," in *Wireless: From Marconi's Black Box to the Audion* (Cambridge, Mass.: MIT Press, 2001), 1–24.

8. "Wireless Transmission of News," *Telephony* 71 (30 Dec. 1916): 32.

9. Edward Bellamy, *Looking Backward, 2000–1887* (Boston: Houghton Mifflin, 1887), 112–15; "Telephonic News Distribution," *Electrical World* 21 (18 Mar. 1893): 212; "Telephone Newspaper," *Electrical World* 22 (4 Nov. 1893): 362.

10. Arthur F. Colton, "The Telephone Newspaper—New Experiment in America," *Telephony* 62 (30 Mar. 1912): 391–92.

11. Bureau of Navigation, Department of Commerce, *Radio Service Bulletin* 61 (1 May 1922): 23–30.

12. K. B. Warner, "The Washington Radio Conference," *QST* 5 (Apr. 1922): 7.

13. *New York Times*, 10 Feb. 1922, quoted in Bensman, *Broadcast Regulation*, 48.

14. K. B. Warner, "The Second National Radio Conference," *QST* 6 (May 1923): 12.

15. Bureau of Navigation, Department of Commerce, *Radio Service Bulletin* 72 (2 Apr. 1923): 11 (emphasis added).

16. Bensman, *Broadcast Regulation*, 136. The Bureau of Navigation's new preference for frequencies was reported in the *Radio Service Bulletin* 72 (2 Apr. 1923): 11–12.

17. According to Bensman, *Broadcast Regulation*, 82, "it was some 15 years later that references to meters in various [government] publications finally stopped."

18. Federal Radio Commission, *Annual Report of the Federal Radio Commission to the Congress of the United States for the Fiscal Year Ended June 30, 1927* (Washington, D.C.: Government Printing Office, 1927), 6.

19. For histories of the commercialization of American radio during the 1920s and 1930s, see Susan Smulyan, *Selling Radio: The Commercialization of American Broadcasting, 1920–1934* (Washington, D.C.: Smithsonian Institution Press, 1994); Robert W. McChesney, *Telecommunications, Mass Media, and Democracy: The Battle for the Control of U.S. Broadcasting, 1928–1935* (New York: Oxford University Press, 1993).

20. Edgar H. Felix, "Will New Transmitting Methods Be the Remedy?" *Radio Broadcast* 13 (May 1928): 5.

21. IEEE History Center, "George W. Pierce," IEEE History Center Web page, www.ieeeahn.org/wiki/index.php/George_W._Pierce, viewed 27 Mar. 2009.

22. James E. Brittain, "Scanning the Past: John R. Carson and Conservation of Radio Spectrum," *Proceedings of the Institute of Electrical and Electronic Engineers* 84 (June 1996): 909. SSB found wide usage in many kinds of telecommunications, and continues to do so today, but it proved impractical for broadcasting. Building a stable single-sideband receiver cost too much for the home radio market during the 1920s; and, besides, the huge number of double-sideband receivers made impractical a changeover on a national scale.

23. Leon J. Sivian, "Means and Method for Signaling by Electric Waves." U.S. Patent No. 1,847,142, application date: 5 Dec. 1923, issue date: 1 Mar. 1932, assigned to Western Electric Company.

24. Clarence W. Hansell, "Phase and Frequency Modulation Applied to Short Wave Communications," 6 Jan. 1932, box 275, microfilm reel, "RCA-7 C.S. & M: 191-M-5923 to 226-M-7212," frame 6329, AP.

25. John Renshaw Carson, "Notes on the Theory of Modulation," *PIRE* 10 (Feb. 1922): 57–64, quotations on pp. 57, 59 (emphasis in original). The *Oxford English Dictionary*, 2d ed., s.v., "frequency modulation," correctly cites this article as the earliest usage of "frequency modulation" and "amplitude modulation."

26. Carson mentioned no specific frequencies in his article. For the purpose of explanation I have chosen to use 100 cps as a modulating frequency and a 1,000,000 cps carrier.

27. Carson, "Notes on the Theory of Modulation."

28. Lawrence P. Lessing, *Man of High Fidelity: Edwin Howard Armstrong* (Philadelphia: J. B. Lippincott, 1956), 199.

29. For examples of similar misinterpretations of Carson, see W. Rupert Maclaurin, *Invention and Innovation in the Radio Industry* (New York: Macmillan, 1949), 185;

and Lessing, *Man of High Fidelity*, 199. Clarence Hansell consistently distorted Carson's argument during the 1930s. In 1932 he stated that "Carson . . . even went so far as to state: 'Consequently this type of modulation (frequency modulation) inherently distorts without any compensating advantages whatsoever.'" Clearly, Hansell implied that Carson was referring to all kinds of frequency modulation. Hansell, "Phase and Frequency Modulation Applied to Short Wave Communications," 6 Jan. 1932. Seven years later, Hansell mentioned "the AT&T attempt to condemn frequency modulation telephony for all time." Hansell to C. H. Taylor, 5 Jan. 1939, box 275, microfilm reel, "RCA-4 C.S. & M: #3435 to #4696," frame 3583, AP. Howard Armstrong grew increasingly contemptuous of mathematical theories of FM, partly because he also believed Carson had erred. In 1943 Armstrong declared in a criticism of author August Hund, that "Carson's [1922] paper . . . made definite predictions of great disadvantages for FM. Whether [Hund], who is essentially a mathematician, resents the fact that in the case of the FM System the experimental method gave the mathematicians a terrible showing up, or whether he has some other motive for covering up the truth, I do not know." This statement indicates that Armstrong either did not understand what Carson had actually said or deliberately misinterpreted Carson. Armstrong to Paul A. de Mars, 4 Apr. 1943, box 7, AP.

30. Lessing, *Man of High Fidelity*, 199–200; Edwin Howard Armstrong, "Mathematical Theory vs. Physical Concept," *FM and Television* 4 (Aug. 1944): 11; John R. Ragazzini, "Creativity in Radio: Contributions of Major Edwin Howard Armstrong," *Journal of Engineering Education* 45 (Oct. 1954): 112–19, reprinted in John W. Morrissey, ed., *The Legacies of Edwin Howard Armstrong* (n.p.: Radio Club of America, 1990), 41; Don V. Erickson, *Armstrong's Fight for FM Broadcasting: One Man vs. Big Business and Bureaucracy* (University: University of Alabama Press, 1973).

31. "John R. Carson," *PIRE* 16 (July 1928): 862; Brittain, "Scanning the Past: John R. Carson and Conservation of Radio Spectrum."

32. Hansell, "Phase and Frequency Modulation Applied to Short Wave Communications," 6 Jan. 1932.

33. Lessing, *Man of High Fidelity*, 200.

34. Albert Hoyt Taylor, "Simultaneous Transmission or Reception of Speech and Signals," U.S. Patent No. 1,376,051, application date: 10 Apr. 1919, issue date: 26 Apr. 1921.

35. John Hays Hammond Jr., "Radio Telegraphy and Telephony," U.S. Patent No. 1,320,685, application date: 29 May 1912, issue date: 4 Nov. 1919.

36. Peter Cooper Hewitt, "System of Electrical Distribution," U.S. Patent No. 1,295,499, application date: 13 Dec. 1913, issue date: 25 Feb. 1919.

37. Albert V. T. Day, "Method and Means for Electrical Signaling and Control," U.S. Patent No. 1,885,009, application date: 25 Jan. 1919, issue date: 25 Oct. 1932.

38. John Hays Hammond Jr., "Transmission of Light by Frequency Variation," U.S. Patent No. 1,977,438, application date: 18 May 1929, issue date: 16 Oct. 1934; and "Transmission of Light Variations by Frequency Variations," U.S. Patent No. 2,036,869, application date: 18 May 1929, issue date: 7 Apr. 1936.

39. Ernst F. W. Alexanderson, "Transmission of Pictures," U.S. Patent No. 1,830,586,

application date: 9 Aug. 1926, issue date: 3 Nov. 1931, assigned to General Electric; Otto Böhm, “Signaling by Frequency Modulation,” U.S. Patent No. 1,874,869, application date: 8 July 1929, issue date: 30 Aug. 1932, assigned to Telefunken Gesellschaft für Drahtlose Telegraphie mbH; Robert B. Dome, “Frequency Modulation,” U.S. Patent No. 1,917,102, application date: 22 July 1929, issue date: 4 July 1933, assigned to General Electric Company; Otto Schriever, “Signaling,” U.S. Patent No. 1,911,091, application date: 3 Sept. 1929, issue date: 23 May 1933, assigned to Telefunken Gesellschaft für Drahtlose Telegraphie mbH; Marian George Wasserman, “Frequency Multiplication,” U.S. Patent No. 1,964,373, application date: 18 Feb. 1931, issue date: 26 June 1934, assigned to Compagnie Générale de Télégraphie Sans Fil; Hans Otto Roosenstein, “Modulation,” U.S. Patent No. 2,001,891, application date: 5 May 1932, issue date: 21 May 1935, assigned to Telefunken Gesellschaft für Drahtlose Telegraphie m; Rudolf Bechmann and Herbert Elstermann, “Frequency Modulation,” U.S. Patent No. 2,076,289, application date: 10 Nov. 1933, issue date: 6 Apr. 1937, assigned to Telefunken Gesellschaft für Drahtlose Telegraphie mbH.

40. The facsimile patents assigned to AT&T before 1933 comprise the following: Pierre Mertz, “Electrical Transmission of Pictures,” U.S. Patent No. 1,548,895, application date: 26 Jan. 1923, issue date: 11 Aug. 1925; Ralph K. Potter, “Electrooptical Image-Producing System,” U.S. Patent No. 1,777,016, application date: 19 May 1928, issue date: 30 Sept. 1930; Roy B. Shanck, “Picture Transmitting System,” U.S. Patent No. 2,115,917, application date: 12 Mar. 1925, issue date: 3 May 1938. Facsimile patents assigned to Western Electric are: Franklin Mohr, “Transmission System,” U.S. Patent No. 1,715,561, application date: 26 May 1926, issue date: 4 June 1929; Maurice B. Long, “Electrical Transmission System,” U.S. Patent No. 1,977,683, application date: 22 May 1926, issue date: 23 Oct. 1934.

41. Charles S. Demarest, “Signaling System,” U.S. Patent No. 2,047,312, application date: 1 Dec. 1926, issue date: 14 July 1936.

42. For a short discussion of Westinghouse’s experimental broadcasting work, see Maclaurin, *Invention and Innovation in the Radio Industry*, 174.

43. H. P. Davis, “The Early History of Broadcasting in the United States,” in Graduate School of Business Administration, Harvard University, *The Radio Industry: The Story of Its Development* (Chicago: A. W. Shaw, 1928): 216; Maclaurin, *Invention and Innovation in the Radio Industry*, 174.

44. George W. Pierce, “Electrical System,” U.S. Patent No. 2,133,642, application date: 25 Feb. 1924, issue date: 18 Oct. 1938.

45. Alexander Nyman, “Combined Wireless Sending and Receiving System,” U.S. Patent No. 1,615,645, application date: 15 July 1920, issue date: 25 Jan. 1927; Donald G. Little, “Wireless Telephone System,” U.S. Patent No. 1,595,794, application date: 30 June 1921, issue date: 10 Aug. 1926, assigned to Westinghouse. Little’s patent appears to contain a typographical error: “The object of my invention,” it reads, “is to provide a modulating system of the above indicated character, wherein the radiated energy is modulated in amplitude rather than in frequency.” This sentence implies that the invention is an amplitude-modulation system, but the remainder of the document clearly describes frequency modulation.

46. FM-related patents filed during the 1920s and assigned to Westinghouse include (in order of their filing dates): Nyman, U.S. Patent No. 1,615,645; Little, U.S. Patent No. 1,595,794; Frank Conrad, “Wireless Telephone System,” U.S. Patent No. 1,528,047, application date: 15 Mar. 1922, issue date: 3 Mar. 1925; John B. Coleman, “Transmitting System,” U.S. Patent No. 1,920,296, application date: 7 Aug. 1926, issue date: 1 Aug. 1933; Frank Conrad, “Radio Communication System,” U.S. Patent No. 2,057,640, application date: 17 Mar. 1927, issue date: 13 Oct. 1936; Virgil E. Trouant, “Radio Transmitting System,” U.S. Patent No. 1,953,140, application date: 18 June 1927, issue date: 3 Apr. 1934; Trouant, “Radiotransmitting System,” U.S. Patent No. 1,872,364, application date: 8 Oct. 1927, issue date: 16 Aug. 1932; Trouant, “Radio Station,” U.S. Patent No. 1,861,462, application date: 3 May 1928, issue date: 7 June 1932; La Verne R. Philpott, “Facsimile Transmission System,” U.S. Patent No. 2,070,312, application date: 21 June 1933, issue date: 9 Feb. 1937.

47. C. W. Horn to Ralph R. Beal, 20 Oct. 1939, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 391, AP.

48. Ibid.

49. Coleman, U.S. Patent No. 1,920,296; Conrad, U.S. Patent No. 2,057,640; Trouant, U.S. Patent No. 1,953,140; Trouant, U.S. Patent No. 1,872,364; Trouant, U.S. Patent No. 1,861,462.

50. Trouant, U.S. Patent No. 1,872,364.

51. Horn to Beal, 20 Oct. 1939.

52. “Half-Million Will Be Spent for Tests: Shepard Starts 50 kw. Plant for Armstrong Experiments,” *BBA* 14 (15 Jan. 1938): 15.

53. Horn to Beal, 20 Oct. 1939.

54. Davis, “Early History,” 219.

55. Mary Texanna Loomis, *Radio Theory and Operating for the Radio Student and Practical Operator*, 4th, rev. ed. (Washington, D.C.: Loomis, 1928), 490–91.

56. Edgar H. Felix, “Will New Transmitting Methods Be the Remedy?” *Radio Broadcast* 13 (May 1928): 5.

57. John Harmon, “Frequency Modulation: A Possible Cure for the Present Congestion of the Ether,” *Wireless World* 29 (22 Jan. 1930): 89.

58. David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (New York: Oxford University Press, 1977), 88.

59. Ibid., 92.

60. Ibid., 93.

61. Barnouw, *Tower in Babel*, 186.

62. Hansell, “Phase and Frequency Modulation Applied to Short Wave Communications,” 6 Jan. 1932.

63. Harold O. Peterson, “Signaling by Frequency Modulation,” U.S. Patent No. 1,789,371, application date: 12 July 1927, issue date: 20 Jan. 1931, assigned to RCA. This patent only barely qualifies as a radiotelephony invention, as it chiefly focuses on a method of FSK telegraphy.

64. Hansell, “Phase and Frequency Modulation Applied to Short Wave Communications,” 6 Jan. 1932.

65. Clarence W. Hansell, “Communication by Frequency Variation,” U.S. Patent No. 1,819,508, application date: 11 Aug. 1927, issue date: 18 Aug. 1931, assigned to RCA; “Oscillation Generation,” U.S. Patent No. 1,787,979, application date: 23 Mar. 1928, issue date: 6 Jan. 1931, assigned to RCA; “Signaling,” U.S. Patent No. 2,103,847, application date: 2 Oct. 1928, issue date: 28 Dec. 1937, assigned to RCA; and “Signaling,” U.S. Patent No. 1,803,504, application date: 5 Oct. 1928, issue date: 5 May 1931, assigned to RCA.

66. “Frequency Modulation in Radio Broadcasting,” *Proceedings of the Radio Club of America* 16 (July 1939): 2.

*Chapter Three • RCA, Armstrong, and the Acceleration of FM Research,
1926–1933*

Epigraph. Beverage to T. J. Boerner, 26 Feb. 1932, box 275, microfilm reel, “RCA-7 C.S. & M: 191-M-5923 to 226-M-7212,” frame 6320, AP.

1. Lawrence P. Lessing, *Man of High Fidelity: Edwin Howard Armstrong* (Philadelphia: J. B. Lippincott, 1956), 219.

2. Alan S. Douglas, “Who Invented the Superheterodyne?” in John W. Morrissey, ed., *The Legacies of Edwin Howard Armstrong* (n.p.: Radio Club of America, 1990), 123–42.

3. Lessing, *Man of High Fidelity*, 98–99.

4. *Ibid.*, 131. Armstrong’s regeneration circuit was the first electronic device that generated continuous radio waves. The superheterodyne circuit greatly simplified the tuning of a radio receiver. The “superhet” also made possible the mass production of inexpensive home radio receivers.

5. *Ibid.*, 146. Ironically, superregeneration, the invention that Armstrong sold for the most money, was never widely used. Lessing also states that Armstrong “chose a good peak of \$114 a share at which to sell a block of his R.C.A. stock just before the Crash, and emerged with a big profit unscathed” (*ibid.*, 182). For additional information about Armstrong’s personal wealth, see Carl Dreher, “E. H. Armstrong: The Hero as Inventor,” *Harper’s*, April 1956, 58, reprinted in Morrissey, *The Legacies of Edwin Howard Armstrong*, 11.

6. “Harold Beverage, Electrical Engineer,” an oral history conducted in 1992 by Frederick Nebecker, IEEE History Center, Rutgers University, New Brunswick, N.J.

7. Harry Tunick to Armstrong, 1 Sept. 1931, box 162, envelope, “Conklin Setters; also RCA etc. Tunick & Sadenwater,” AP.

8. Tunick to Armstrong, 19 Oct. 1931, box 162, envelope, “Conklin Setters; also RCA etc. Tunick & Sadenwater,” AP.

9. Edwin H. Armstrong, “Radio Telephone Signaling,” U.S. Patent No. 1,941,447, application date: 18 May 1927, issue date: 26 Dec. 1933.

10. Harold O. Peterson, “Signaling by Frequency Modulation,” U.S. Patent No. 1,789,371, application date: 12 July 1927, issue date: 20 Jan. 1931, assigned to RCA.

11. Hugh G. J. Aitken, *Continuous Wave: Technology and American Radio, 1900–1932* (Princeton: Princeton University Press, 1985), 450–52.

12. Eugene Lyons, *David Sarnoff: A Biography* (New York: Harper & Row, 1966), 155–61.
13. Unknown RCA author, “Minutes of Meeting for Development Coordination,” 1 Aug. 1929, box 275, AP.
14. Shelby’s assessment is quoted in P. D. McKeel, “Description of Westinghouse Frequency Modulation Receiver,” Aug.–Sept. 1930, box 275, AP.
15. Crosby to Beverage, 18 Dec. 1930, box 275, microfilm reel, “RCA-7 C.S. & M: 191-M-5923 to 226-M-7212,” frame 7127, AP.
16. V. D. Landon, “An Analysis of Frequency Modulation,” ca. 7 Sept. 1929, box 275, microfilm reel, “RCA-7 C.S. & M: 191-M-5923 to 226-M-7212,” frame 7164, AP.
17. Hansell to C. H. Taylor, 7 Sept. 1929, box 275, microfilm reel, “RCA-7 C.S. & M: 191-M-5923 to 226-M-7212,” frame 7163, AP.
18. Murray G. Crosby, “Theoretical and Experimental Analysis of the Transmitted Wave Form of a Frequency Modulation System,” memorandum, 14 June 1930, box 275, AP.
19. Beverage to Alfred Norton Goldsmith, 21 July 1930, box 275, AP; Goldsmith to Beverage, 6 Aug. 1930, box 275, AP.
20. Beal to Hansell, 21 Oct. 1930, box 275, microfilm reel, “Cravath, Swaine & Moore Folder #190M: Index 90 to #5922,” frame 5271, AP.
21. Beverage to Beal, 13 Jan. 1931, box 275, microfilm reel, “Cravath, Swaine & Moore Folder #190M: Index 90 to #5922,” frame 5089, AP; also, box 275, microfilm reel, “RCA-7 C.S. & M: 191-M-5923 to 226-M-7212,” frame 7122, AP.
22. Hansell to Conklin, “RD-1105—Frequency Modulation Experiments,” memorandum, 27 June 1931, box 159, AP. Armstrong’s transmitter and receiver were patented in Edwin H. Armstrong, “Radio Signaling System,” U.S. Patent No. 1,941,066, application date: 30 July 1930, issue date: 26 Dec. 1933.
23. Hansell to Conklin, 27 June 1931.
24. *Ibid.*
25. *Ibid.*
26. *Ibid.*
27. *Ibid.*
28. *Ibid.*
29. Beal to Beverage, 7 July 1931, box 275, AP; copy of telegram, “McKesson, Manila to Conklin, Bolinas,” undated attachment to Hansell to Armstrong, 16 July 1931, box 161, AP.
30. Beal to Beverage, 7 July 1931.
31. Armstrong to Hansell, 22 July 1931, box 162, envelope, “Conklin Setters; also RCA etc. Tunick & Sadenwater,” AP.
32. Crosby to Armstrong, 8 Mar. 1932, box 160, AP; microfilmed copy in box 275, microfilm reel, “Cravath, Swaine & Moore Folder #190M: Index 90 to #5922,” frame 5425, AP.
33. Beverage to T. J. Boerner, 26 Feb. 1932, box 275, microfilm reel, “RCA-7 C.S. & M: 191-M-5923 to 226-M-7212,” frame 6320, AP.

34. Hansell to Beverage, 6 Jan. 1932, box 275, microfilm reel, “RCA-7 C.S. & M: 191-M-5923 to 226-M-7212,” frame 6326, AP.

35. Clarence W. Hansell, “Phase and Frequency Modulation Applied to Short Wave Communications,” 6 Jan. 1932, box 275, microfilm reel, “RCA-7 C.S. & M: 191-M-5923 to 226-M-7212,” frame 6329, AP.

36. Hansell to Beverage, 6 Jan. 1932.

37. Beverage to Tunick, 8 Apr. 1932, box 160, AP.

38. Murray G. Crosby, “Frequency Modulation Propagation Characteristics,” *PIRE* 24 (June 1936): 898–913.

39. Armstrong’s paper was originally presented to the IRE on 6 Nov. 1935, Crosby’s two days earlier. Edwin Howard Armstrong, “A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation,” *PIRE* 24 (May 1936): 689–740.

40. Armstrong repeated Hansell’s distortion of the critique of frequency modulation that Carson published in 1922. In 1932 Hansell wrote that “Dr. [Frank] Conrad was credited with statements to the effect that frequency modulation did not produce side frequencies as in amplitude modulation and would therefore permit a great increase in the number of broadcasting stations. The incorrectness of this assumption was pointed out by Dr. John R. Carson, who even went so far as to state: ‘Consequently this type of modulation (frequency modulation) inherently distorts without any compensating advantages whatsoever.’” Hansell, “Phase and Frequency Modulation Applied to Short Wave Communications,” 6 Jan. 1932. Six years later, Armstrong wrote in his famous paper on FM, “The subject of frequency modulation seemed forever closed with Carson’s final judgment, rendered after a thorough consideration of the matter, that ‘Consequently this method of modulation inherently distorts without any compensating advantages whatsoever.’” Armstrong, “A Method of Reducing Disturbances,” 690.

Chapter Four • The Serendipitous Discovery of Staticless Radio, 1915–1935

Epigraphs. Walpole to Horace Mann, 28 Jan. 1754, quoted in Theodore G. Remer, *Serendipity and the Three Princes, from the Peregrinaggio of 1557* (Norman: University of Oklahoma Press, 1965), 6 (emphasis in original manuscript). The author thanks Richard Boyle, whose articles in the *Sunday Times* (Colombo, Sri Lanka) called attention to Walpole’s original sense of the word “serendipity,” as well as to Remer’s book, which makes the same point. See Richard Boyle, “Serendipity and the Three Princes, Part One,” *Sunday Times*, 30 July 2000, and “Serendipity and the Three Princes, Part Two,” *Sunday Times*, 6 Aug. 2000.

1. For a list of “serendipity patterns” in science and technology, see Pek van Anel, “Anatomy of the Unsought Finding: Serendipity: Origins, History, Domains, Traditions, Appearances, Patterns and Programmability,” *British Journal for the Philosophy of Science* 45 (June 1994): 631–48. Anel reaffirms earlier scholars’ observations that the role of chance in discovery has been recognized by scientists and scholars since

the ancient Greeks. The best known aphorism about the role of chance in scientific discovery is Louis Pasteur's "Chance favors the prepared mind," although van Andel points out that this is a slight mistranslation from what Pasteur actually said, namely: "In the sciences of observation, chance favors only prepared minds" (*ibid.*, 634–635). Remer examines instances of "accidental sagacity" in scientific and technological discovery, such as John Morehead's discovery of an inexpensive method of producing acetylene. Theodore G. Remer, "The Nature of Serendipity," in *Serendipity and the Three Princes, from the Peregrinaggio of 1557* (Norman: University of Oklahoma Press, 1965), 167–77.

2. Lawrence P. Lessing, *Man of High Fidelity: Edwin Howard Armstrong* (Philadelphia: J. B. Lippincott, 1956), 71.

3. *Ibid.*, 196.

4. The linear balanced amplifier was also called, depending on its specific configuration and usage, a differential amplifier, a push-pull amplifier, or a class AB amplifier.

5. John Renshaw Carson, "Method and Means for Signaling with High-Frequency Waves," U.S. Patent No. 1,449,382, application date: 1 Dec. 1915, issue date: 27 Mar. 1923, assigned to AT&T; and "Duplex Translating-Circuits," U.S. Patent No. 1,343,307, application date: 5 Sept. 1916, issue date: 15 June 1920, assigned to AT&T.

6. Clarence W. Hansell, "Coupling," U.S. Patent No. 1,751,996, date of application: 18 Jan. 1927, date of issue: 25 Mar. 1930, assigned to RCA; "Oscillation Generation," U.S. Patent No. 1,787,979, application date: 23 Mar. 1928, issue date: 6 Jan. 1931, assigned to RCA; "Signaling," U.S. Patent No. 1,803,504, application date: 5 Oct. 1928, issue date: 5 May 1931, assigned to RCA; "Communication by Frequency Variation," U.S. Patent No. 1,819,508, application date: 11 Aug. 1927, issue date: 18 Aug. 1931, assigned to RCA; "Frequency Modulation," U.S. Patent No. 1,830,166, application date: 23 Mar. 1928, issue date: 3 Nov. 1931, assigned to RCA; "Detection of Frequency Modulated Signals," U.S. Patent No. 1,867,567, application date: 1 Feb. 1929, issue date: 19 July 1932, assigned to RCA; "Frequency Multiplier and Amplifier," U.S. Patent No. 1,878,308, application date: 23 Mar. 1927, issue date: 20 Sept. 1932, assigned to RCA; "Detection of Frequency Modulated Signals," U.S. Patent No. 1,922,290, application date: 14 May 1930, issue date: 15 Aug. 1933, assigned to RCA; "Frequency Modulation," U.S. Patent No. 2,027,975, application date: 25 June 1930, issue date: 14 Jan. 1936, assigned to RCA; "Signaling," U.S. Patent No. 2,103,847, application date: 2 Oct. 1928, issue date: 28 Dec. 1937, assigned to RCA; and "Signaling," U.S. Patent No. 2,167,480, application date: 2 Nov. 1927, issue date: 25 July 1939, assigned to RCA.

7. Edwin Howard Armstrong, "Some Recent Developments in the Audion Receiver," *PIRE* 3 (Sept. 1915): 215–47, reprinted in John W. Morrissey, ed., *The Legacies of Edwin Howard Armstrong* (n.p.: Radio Club of America, 1990), 189–216; also reprinted in *Proceedings of the IEEE* 85 (Apr. 1997): 685–97.

8. Edwin H. Armstrong. "Operating Features of the Audion," *Electrical World* 64 (12 Dec. 1914): 1149–52. For the testy exchange between Armstrong and de Forest, see the discussion that follows Armstrong, "Some Recent Developments."

9. Armstrong, "Some Recent Developments," 234, 236, 238.

10. Michael I. Pupin and Edwin Howard Armstrong, "Radioreceiving System

Having High Selectivity,” U.S. Patent No. 1,416,061, application date: 18 Dec. 1918, issue date: 16 May 1922.

11. Edwin Howard Armstrong, “Wave Signaling System,” U.S. Patent No. 1,716,573, application date: 24 Feb. 1922, issue date: 11 June 1929.

12. Edwin Howard Armstrong, “Radio Signaling System,” U.S. Patent No. 2,082,935, application date: 6 Aug. 1927, issue date: 8 June 1937; and, “Methods of Reducing the Effects of Atmospheric Disturbance,” *PIRE* 16 (Jan. 1928): 15–26.

13. John Renshaw Carson, “The Reduction of Atmospheric Disturbances,” *PIRE* 16 (July 1928): 966–75, quotations on pp. 966, 974, 966.

14. Edwin H. Armstrong, “Radio Telephone Signaling,” U.S. Patent No. 1,941,447, application date: 18 May 1927, issue date: 26 Dec., 1933.

15. *Ibid.*

16. Edwin Howard Armstrong, “Radio Signaling System,” U.S. Patent 1,941,066, application date: 30 July 1930, issue date: 26 Dec. 1933.

17. Murray G. Crosby, “Phase Modulation Receiver,” U.S. Patent No. 2,101,703, application date: 23 Jan. 1932, issue date: 7 Dec. 1937, assigned to RCA.

18. Ellison S. Purington, “Fortune Magazine, October, 1939,” memorandum, 25 Oct. 1939, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 364, AP.

19. Edwin H. Armstrong, “Radiosignaling,” U.S. Patent No. 1,941,068, application date: 24 Jan. 1933, issue date: 26 Dec. 1933; and “Radiosignaling,” U.S. Patent No. 1,941,069, application date: 24 Jan. 1933, issue date: 26 Dec. 1933.

20. Armstrong, U.S. Patent No. 1,941,069.

21. The FCC can more easily regulate broadcast FM than AM for two technical reasons. First, FM operates in a part of the spectrum where propagation is limited to a few miles beyond “line of sight.” Also, FM receivers sort out overlapping signals far better than do AM receivers.

22. Armstrong, U.S. Patent No. 1,941,068.

23. *Ibid.*

24. Armstrong, U.S. Patent No. 1,941,069.

25. *Ibid.* (emphasis added).

26. Armstrong, U.S. Patent No. 1,941,447.

27. Armstrong, U.S. Patent No. 1,941,069.

28. *Ibid.*

29. *Ibid.* (emphasis added).

30. *Ibid.*

31. J. C. Johnson, “Thermal Agitation of Electricity in Conductors,” *Physical Review* 32 (July 1928): 97–109.

32. Armstrong, U.S. Patent No. 1,941,069.

33. Edwin Howard Armstrong, “Demonstration of Reduction of Tube Noise by Frequency Modulation at 7.5 meters,” hand-drawn sketch, 21 July 1932, box 159, AP.

34. Armstrong to Moses & Nolte, 23 Aug. 1932, box 245, AP; Armstrong, U.S. Patent No. 1,941,069. Moses and Nolte were Armstrong’s patent lawyers.

35. Armstrong, U.S. Patent No. 1,941,069.

36. *Ibid.*

37. Armstrong to Gano Dunn, 22 June 1939, box 163, AP. In 1935 Armstrong stated that FM's first demonstration "was early in 1934 to a group of scientists." "Radio Device Ending Fading, Static Reported," *New York Herald Tribune*, 26 Apr. 1935.

38. Harold H. Beverage, "History of Frequency Modulation Development in R.C.A. Communications, Inc.," memorandum, 27 Oct. 1939, box 275, microfilm reel, "RCA-1 C.S. & M: #1 to #1419," frame 386, AP.

39. Crosby, "Crosby Notebook," 5 Jan. 1934, box 160, manila envelope, "Notes from Laporte's Original examination," AP.

40. Beverage to Taylor, 15 June 1934, box 275, microfilm reel, "Cravath, Swaine & Moore Folder #190M: Index 90 to #5922," frame 5205, AP.

41. For descriptions of the Empire State Building Television Laboratory FM tests, see Edwin Howard Armstrong, "A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation," *PIRE* 24 (May 1936): 717–40; Thomas J. Buzalski, "Field Test of the Armstrong Wide-Band Frequency Modulation System from the Empire State Building, 1934 and 1935" *A.W.A. Review* 1 (1986): 109–16, reprinted in Morrisey, *The Legacies of Edwin Howard Armstrong*, 244–50.

42. Radio Corporation of America, *Annual Report, 1933* (New York: RCA, 1934), 6.

43. Beverage to Charles J. Young, 8 Apr. 1932, box 275, microfilm reel, "RCA-7 C.S. & M: 191-M-5923 to 226-M-7212," frame 5972, AP.

44. Record of visitors to Empire State Building, 12 Jan. 1934, cited by Buzalski, "Field Test of the Armstrong Wide-Band Frequency Modulation System," 110.

45. Beverage to Taylor, 15 June 1934.

46. In 1920 Armstrong had sold to Westinghouse his patent rights to feedback and two other inventions for an immediate payment of \$350,000, and—if the courts ruled in favor of Armstrong—an additional \$200,000.

47. Lessing, *Man of High Fidelity*, 51, 130–31.

48. *Ibid.*, esp. 158–93.

49. Quoted in *ibid.*, 189.

50. *Ibid.*, 190.

51. R. E. Shelby, "Monthly Report, March 1934," memorandum, 31 Mar. 1934, box 275, microfilm reel, "RCA-1 C.S. & M: #3436 to #4696," frame 3925, AP.

52. Armstrong, "Method for Reducing Disturbances," 717–18.

53. Shelby, "Monthly Report, March 1934."

54. Buzalski, "Field Tests of the Armstrong Wide-Band Frequency Modulation System," 113.

55. *Ibid.*; R. E. Shelby, "Monthly Report: Empire State Television Laboratory," memorandum, 31 May 1934, box 275, microfilm reel, "RCA-1 C.S. & M: #3436 to #4696," frame 3927, AP.

56. Tunick to Mr. Martin, 23 May 1934, box 164, envelope, "Miscellaneous RCA Notes and Records," AP.

57. Armstrong, "Method of Reducing Disturbances," 718.

58. George E. Burghard, "Eighteen Years of Amateur Radio," *Radio Broadcast* 2 (Aug. 1923): 290.

59. Hansell to Beverage, 20 June 1934, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frames 12 and 400, AP.
60. Lessing, *Man of High Fidelity*, 221.
61. Armstrong, “Method of Reducing Disturbances,” 720.
62. Beverage to Taylor, 15 June 1934.
63. Ibid.
64. Hansell to Beverage, 20 June 1934.
65. Ibid.
66. Ibid.
67. R. E. Shelby, “Monthly Report,” memorandum, 2 July 1934, box 275, microfilm reel, “RCA-1 C.S. & M: #3436 to #4696,” frame 3928, AP.
68. Sadenwater to Wozencraft, 15 Mar. 1940, box 159, AP.
69. Beverage to Beal, 28 July 1935, box 275, microfilm reel, “Cravath, Swaine & Moore Folder #190M: Index 90 to #5922,” frame 5104, AP.
70. Hansell to Beverage, 29 July 1935, box 275, microfilm reel, “Cravath, Swaine & Moore Folder #190M: Index 90 to #5922,” frame 5410, AP.
71. Ibid.
72. Charles M. Burrill, “Status Report for Weeks of October 15 and 22, 1934,” memorandum, 22 Oct. 1934, box 159, AP.
73. Charles M. Burrill, “Status Report for Weeks of Oct. 29 and Nov. 5, 1934,” memorandum, 7 Nov. 1934, box 159, AP.
74. Charles M. Burrill, “Notes on the Reception of Amplitude and Wide-Band Frequency Modulated Signals from the Empire State Transmitter, Dec. 12 to 14, 1934, at 22 Mountain View Rd., Millburn, N.J.,” memorandum, 23 Jan. 1935, box 159, AP.
75. Lessing, *Man of High Fidelity*, 226.
76. Ibid., 225. To date, a copy of this letter has not been found.
77. FCC, *Report on Chain Broadcasting* (Washington, D.C.: Government Printing Office, 1941), 18–20.
78. *Radio Corporation of America, Seventeenth Annual Report: Radio Corporation of America, Year Ended December 31, 1936* (New York: RCA, 1937), 11–12.
79. FCC, *Report on Chain Broadcasting*, 14–15.
80. Ibid., 18–20. This part of the report described the wide-ranging subsidiaries of RCA, warning of “broader problems raised by this concentration of power in the hands of a single group.”
81. Elmer Engstrom to Baker, 12 March 1935, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 438, AP.
82. Baker to Schairer, 19 Mar. 1935, box 183, and box 164, envelope labeled “Miscellaneous RCA Notes and Records,” AP.
83. Beal to Schairer, 14 May 1935, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 227, AP.
84. Beal, “Comments on the Characteristics of the Armstrong Wide Band Frequency Modulation System and Suggestions for Field Tests Related to Extension of Field Test Area,” memorandum, 9 July 1935, box 275, microfilm reel, “Cravath, Swaine & Moore Folder #190M: Index 90 to #5922,” frame 5415, AP.

85. “Radio Device Ending Fading, Static Reported: Armstrong Perfects Method Increasing Range of Ultra-Short Wave Broadcasting,” *New York Herald Tribune*, 26 Apr. 1935.
86. “Radio Invention Helps End Static,” *New York Times*, 26 Apr. 1935.
87. “Major Armstrong Fights Static,” *Electronics* 8 (May 1935): 162.
88. “Events of the Future Foretold,” *Electronics* 8 (June 1935): 203.
89. “A Treatise on Frequency Modulation,” *Communication and Broadcast Engineering* 2 (June 1935): 18; “Technical Topics: Frequency Modulation: Major Armstrong,” *QST* 19 (Sept. 1935): 21.
90. Armstrong to Beal, 5 Aug. 1935, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 540, AP.
91. Baker to Armstrong, 5 Aug. 1935, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 444, AP.
92. Armstrong to Beal, 12 Aug. 1935, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 496, AP.
93. Harold H. Beverage, Harold O. Peterson, Murray G. Crosby, Bertram Trevor, and Charles Burrill, “F-18-7: Wide Band Frequency Modulation Tests,” memorandum, 9 Oct. 1935, box 275, microfilm reel, “Cravath, Swaine & Moore Folder #190M: Index 90 to #5922,” frame 5862, AP.

*Chapter Five • FM Pioneers, RCA, and the Reshaping of Wideband FM Radio,
1935–1940*

- Epigraphs. [Lawrence P. Lessing], “Revolution in Radio,” *Fortune* 20 (Oct. 1939):
86. Ellison S. Purington, “Fortune Magazine, October, 1939,” memorandum, 25 Oct. 1939, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 364, AP.
1. Young to Armstrong, 1 Nov. 1935, box 162, envelope, “Conklin Setters; also RCA etc. Tunick & Sadenwater,” AP; Armstrong to Young, 6 Nov. 1935, box 162, envelope, “Conklin Setters; also RCA etc. Tunick & Sadenwater,” AP.
2. Beal to Schairer, 7 Nov. 1935, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 229, AP.
3. Donald G. Fink, “Phase-Frequency Modulation,” *Electronics* 8 (Nov. 1935): 17; “Armstrong Demonstrates Frequency Modulation System,” *Communication and Broadcast Engineering*, Nov. 1935, 21.
4. Lawrence P. Lessing, *Man of High Fidelity: Edwin Howard Armstrong* (Philadelphia: J. B. Lippincott, 1956), 209–10.
5. “Editorial: High-Quality Programs,” *Communication and Broadcast Engineering*, Nov. 1935, 4.
6. Edwin H. Armstrong, “Radiosignaling,” U.S. Patent No. 1,941,068, application date: 24 Jan. 1933, issue date: 26 Dec. 1933.
7. Thomas J. Buzalski, “Field Tests of the Armstrong Wide-Band Frequency Modulation System from the Empire State Building, 1934 and 1935,” *A.W.A. Review* 1 (1986): 109–16, reprinted in John W. Morrissey, ed., *The Legacies of Edwin Howard Armstrong* (n.p.: Radio Club of America, 1990), 244–50.

8. Beal to Schairer, 7 Nov. 1935.
9. Gleason L. Archer, *History of Radio to 1926* (New York: American Historical Society, 1938), 284–87; FCC, *Report on Chain Broadcasting* (Washington, D.C.: Government Printing Office, 1941), 5–6.
10. “Regionals Form Organization with Shepard Named President: Permanent Setup Adopted at Meeting in Chicago; Advocate 5,000 Watts Both Night and Day,” *BBA* 14 (15 May 1938): 14.
11. See Susan Smulyan, *Selling Radio: The Commercialization of American Broadcasting, 1920–1934* (Washington, D.C.: Smithsonian Institution Press, 1994); and Robert W. McChesney, *Telecommunications, Mass Media, and Democracy: The Battle for the Control of U.S. Broadcasting, 1928–1935* (New York: Oxford Press, 1993).
12. This is the central argument in Charles A. Siepmann’s book, *Radio’s Second Chance* (Boston: Atlantic-Little, Brown Books, 1946). For somewhat different, largely commercial, reasons, editor Milton B. Sleeper also called FM “radio’s second chance” in “Revolution for Profit,” *FM* 1 (Nov. 1940): 3.
13. [Lawrence P. Lessing], “Revolution in Radio,” *Fortune* 20 (Oct. 1939); Alfred Toombs, “The Radio Battle of 1941: FM vs. AM,” *Radio News*, Mar. 1941, 7; Harry Sadenwater to F. R. Deakins, 15 May 1936, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 551, AP.
14. Beal to Schairer, 13 Dec. 1937, box 275, microfilm reel, “RCA-1 C.S. & M: #1 to #1419,” frame 565, AP.
15. Bruce Robertson, “Armstrong Soon to Start Staticless Radio: Broad Claims for New System Are Made,” *BBA* (1 Feb. 1939): 19.
16. “Yankee Frequency Modulation About Ready: Armstrong Method to Go on Air in June,” *BBA* 16 (1 June 1939): 19.
17. Armstrong to Andrew Ring, 27 Apr. 1936, box 423, AP; “High Power Frequency Modulation,” *Electronics* 9 (May 1936): 25; “Maj. Armstrong Granted CP for 40 kw. Apex Test,” *BBA* 10 (15 June 1936): 51.
18. Edwin Howard Armstrong, “Application for Modification of Radio Station Construction Permit,” 24 Apr. 1936, box 5, AP.
19. Donald G. Fink, “From the Mountaintops,” *Technology Review* 41 (Apr. 1939): 257.
20. Donald G. Fink, “FM Gets Its ‘Day in Court,’” *Electronics* 13 (Apr. 1940): 14.
21. Harry Sadenwater to C. K. Throckmorton, memorandum, 16 Mar. 1938, box 159, AP.
22. “High-Fidelity Signals Free from Static Are Shown in Tests by Maj. Armstrong,” *BBA* 16 (1 Apr. 1939): 81.
23. Henry M. Lane, “Engineers Hail Noiseless Radio,” *Boston Sunday Post*, 28 May 1939. The author thanks Donna Halper for sharing this article. That Lessing lists identical high-fidelity sound effects—for example, tearing paper, pouring water, and the striking of a bell—in his similarly worded description of the November 1935 IRE demonstration suggests that he used this article as a source for his description of the IRE event.
24. *Ibid.*

25. To clarify, FM receivers can sort out two incoming signals if one signal is at least 3 dB stronger than the other. In other words, the power ratio of the two signals must be at least 2.0. Bruce Robertson, “Armstrong Soon to Start Staticless Radio: Broad Claims for New System Are Made,” *BBA* 16 (1 Feb. 1939): 19; “High-Fidelity Signals Free from Static Are Shown in Tests by Maj. Armstrong,” *BBA* 16 (1 Apr. 1939): 81; Irwin R. Weir, “Field Tests of Frequency- and Amplitude-Modulation with Ultrahigh-Frequency Waves, Part I,” *General Electric Review* 42 (May 1939): 188–91; Irwin R. Weir, “Field Tests of Frequency- and Amplitude-Modulation with Ultrahigh-Frequency Waves, Part II,” *General Electric Review* 42 (June 1939): 270–73.

26. “High-Fidelity Signals Free from Static Are Shown in Tests by Maj. Armstrong,” 81.

27. “Half-Million Will Be Spent for Tests: Shepard Starts 50 kw. Plant for Armstrong Experiments,” *BBA* 14 (15 Jan. 1938): 15.

28. The 5,000-cycle limitation for long-distance telephone lines was mentioned in an anonymous internal RCA memorandum: “Transmitter Advanced Development Section, Radio Corporation of America. Frequency Modulation: A brief discussion of its principles of operation, the claimed advantages and disadvantages, activities outside of and within RCA companies, and engineering work to be done,” Dec. 1939, box 159, AP.

29. Henry M. Lane, *Boston Sunday Post*, 7 Jan. 1940, cited by “First F-M Network Broadcast: Yonkers Program Received in Boston through Use of Four Experimental Transmitters,” *BBA* 18 (15 Jan. 1940): 32.

30. “F-M Broadcasting on Three Relays Proves Successful: Armstrong and Doolittle See Widespread Radio Changes,” *BBA* 17 (15 Dec. 1939): 26.

31. “Broadcasters Organize Group for Operation of F-M Stations: Charter Sought after New York Meeting as Plans Are Laid; Shepard Elected Chairman,” *BBA* 18 (15 Jan. 1940): 31.

32. *Ibid.*

33. “Yankee Asks FCC for Regular License for 50 kw. F-M Station in New York,” *BBA* 17 (1 Nov. 1939): 64.

34. “Jett Orders F-M Study,” *BBA* 17 (1 Dec. 1939): 77.

35. The date of the hearing was originally scheduled for 28 February, but at Armstrong’s request the FCC postponed the meeting by three weeks. “FCC to Investigate Progress of FM: All Phases of New Art Will Be Probed at Hearing,” *BBA* 18 (1 Jan. 1940): 19. The FCC’s official notice was reprinted in “Agenda of Feb. 28 Hearing on Frequency Modulation,” *BBA* 18 (1 Jan. 1940): 19; “Armstrong Asks Delay Pending F-M Study,” *BBA* 18 (1 Feb. 1940): 70.

36. Murray G. Crosby, “Frequency Modulation Propagation Characteristics,” *PIRE* 24 (June 1936): 898–913; “Frequency Modulation Noise Characteristics,” *PIRE* 25 (Apr. 1937): 472–514; “Carrier and Side-Frequency Relations with Multi-Tone Frequency or Phase Modulation,” *RCA Review* 3 (July 1938): 103–7; “Communication by Phase Modulation,” *PIRE* 27 (Feb. 1939): 126–36; and “The Service Range of Frequency Modulation,” *RCA Review* 4 (Jan. 1940): 349–71.

37. Baker to Armstrong, 29 Nov. 1937, box 244, AP.

38. Sadenwater to Wozencraft, 15 Mar. 1940, box 159, AP.
39. Beal to Schairer, 13 Dec. 1937.
40. Hansell to Armstrong, 2 June 1936, box 183, AP.
41. Sadenwater to Deakins, 15 May 1936.
42. Sadenwater to J. L. Schwank, 13 Jan. 1937, box 183, AP.
43. Sadenwater to Throckmorton, 16 Mar. 1938.
44. Ibid.
45. Ibid.
46. Dale Pollack, "Suggestions for Future Development Projects," memorandum, 13 Sept. 1937, box 163, AP.
47. For a biography of Baker, see "Walter R. G. Baker: 1892–1960," Web page, www.ieee.org/web/aboutus/history_center/biography/baker.html, viewed 3 Apr. 2009.
48. Dale Pollack, "Report on Trip to the Convention: Rochester, November, 1938," memorandum, 21 Nov. 1938, box 163, AP. Also, box 183, AP.
49. Dale Pollack, "Frequency Modulation Development Program," memorandum, 22 Nov. 1938, box 163, AP.
50. O. B. Hanson to Lenox R. Lohr, 18 Jan. 1939, box 275, microfilm reel, "No. RCA-2, first original #1420, last original #3089," frame 2350, AP.
51. Pollack, "Frequency Modulation Development Program."
52. Hansell to Niles Trammell, 25 May 1939, box 244, AP.
53. Hanson to Lohr, 24 Jan. 1939, box 275, microfilm reel, "No. RCA-2, first original #1420, last original #3089," frame 2318, AP.
54. Ibid.
55. "Frequency Modulation: A Revolution in Broadcasting?" *Electronics* 13 (Jan. 1940): 10.
56. F. R. Deakins to Lewis M. Clement, 28 Sept. 1939, box 183, AP.
57. Hansell to Trammell, 25 May 1939.
58. Trammell to Hanson, 31 May 1939, box 244, AP.
59. Beal to Clement, 15 May 1939, box 275, microfilm reel, "RCA-1 C.S. & M: #3436 to #4696," frame 4447, AP.
60. R. D. Duncan Jr. to Clement and Pollack, 9 June 1939, box 183, AP.
61. Hanson to Lohr, 28 Aug. 1939, box 275, microfilm reel, "RCA-4 C.S. & M: #3435 to #4696," frame 3520, AP.
62. Hanson to Lohr, 15 Sept. 1939, box 275, microfilm reel, "RCA-4 C.S. & M: #3435 to #4696," frame 3522. Also, reel #2, frame 2358, AP.
63. See, for example: [Lessing], "Revolution in Radio"; "Armstrong's Threat to Upset Radio Appletart Marked by FM-Television Battle for Bands," *Newsweek*, 1 Apr. 1940: 30.
64. Orrin E. Dunlap Jr., "Divided Opinions," *New York Times*, 17 Mar. 1940; Lewis V. Gilpin and Sol Taishoff, "Birth of Commercial FM This Year Seen," *BBA* (1 Apr. 1940): 18.
65. Gilpin and Taishoff, "Birth of Commercial FM This Year Seen," 19.
66. Fink, "FM Gets Its 'Day in Court,'" 15.
67. Gilpin and Taishoff, "Birth of Commercial FM This Year Seen."

68. Fink, “FM Gets Its ‘Day in Court.’”
69. Gilpin and Taishoff, “Birth of Commercial FM This Year Seen.”
70. *Ibid.*
71. FCC, “In the Matter of Aural Broadcasting on Frequencies above 25,000 kilocycles Particularly Relating to Frequency Modulation,” Docket No. 5805, 20 May 1940. Document available from FCC Web page, www.fcc.gov.

Conclusion

Epigraphs. John R. Poppele, “FM and Its Economic Advantages,” *Proceedings of the Radio Club of America* 17 (Oct. 1940): 11–12. Robert Angus, “What’s Wrong with American FM?” *Popular Electronics* 16 (June 1962): 45.

1. John Law, “Technology, Closure, and Heterogeneous Engineering: The Case of the Portuguese Expansion” in Wiebe E. Bijker, Thomas Parke Hughes, and Trevor J. Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, Mass.: MIT Press, 1987), 111–34.

2. Boelie Elzen, Bert Enserink, and Wim A. Smit, “Socio-Technical Networks: How a Technology Studies Approach May Help to Solve Problems Related to Technological Change,” *Social Studies of Science* 26, no. 1 (Feb. 1996): 95–141.

3. “FM to Establish New York Office; Dorrance Named,” *BBA* 18 (1 June 1940): 14.

4. Donald MacKenzie and Judy Wajcman, “Introductory Essay: The Social Shaping of Technology,” in Mackenzie and Wajcman, eds., *The Social Shaping of Technology*, 2d ed. (Buckingham: Open University Press, 1999), 3–27, quotation on p. 4.

5. Thomas Jay Misa, “Retrieving Sociotechnical Change from Technological Determinism,” in Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, Mass.: MIT Press, 1994), 115–42, quotation on p. 117.

6. Walter G. Vincenti, “The Technical Shaping of Technology: Real-World Constraints and Technical Logic in Edison’s Electrical Lighting System,” *Social Studies of Science* 25, no. 3 (Aug. 1995): 553–74, quotation on p. 556.

7. For more about technologies with “embedded” politics, see Langdon Winner, “Do Artifacts Have Politics?” *Daedalus* 109 (Winter 1980): 121–36.

8. The commercial schedule was reported as “Operating power: 250 w. or less, \$300; 1 kw., \$500; 2 kw., \$750; 5 kw., \$1,250; 10 kw., \$2,000; 20 kw., \$3,000; 30 kw., \$3,750; 40 kw., \$4,500; 50 kw. or more, \$5,000 for 50 kw.; \$50 for each additional kw.” See “Armstrong Fixes Royalty Payments,” *BBA* 18 (15 Jan. 1940): 31.

9. See Charles A. Siepmann, *Radio’s Second Chance* (Boston: Atlantic-Little, Brown Books, 1946).

10. “Finally, FCC Okays Stereo,” *Broadcasting* 60 (19 Apr. 1961): 65–66. The FCC considered several methods of implementing stereophonic broadcasts, including one by Murray Crosby. The commission chose a design developed jointly by General Electric and Zenith.

11. Christopher H. Sterling and John Michael Kittross, *Stay Tuned: A Concise His-*

tory of *American Broadcasting* (Mahwah, N.J.: Lawrence Erlbaum Associates, 2001), 828.

12. Angus, “What’s Wrong with American FM?”

13. *Ibid.*

14. Woody Allen, director, *Annie Hall*, distributed by United Artists, 1977.

15. Susan J. Douglas, *Listening In: Radio and the American Imagination, from Amos 'n' Andy and Edward R. Murrow to Wolfman Jack and Howard Stern* (New York: Times Books, 1999), 256–84; Christopher H. Sterling and Michael C. Keith, *Sounds of Change: A History of FM Broadcasting in America* (Chapel Hill: University of North Carolina Press, 2008).

16. “FM Signals Follow Several Horizons, Armstrong Tells Indiana Radio Session,” *BBA* 19 (1 July 1940): 52. It should be noted that Armstrong made this point to support the dubious claim that the past teaches that “everything that has been accomplished in science was at one time sworn to be impossible.”

17. John R. Poppele, “FM and Its Economic Advantages,” *Proceedings of the Radio Club of America* 17 (Oct. 1940): 11–12.

18. For information about low-power FM, see the Prometheus Radio Project Web page, www.prometheusradio.org, viewed 3 April 2009. For FCC documents about low-power FM, see the FCC Web page, www.fcc.gov.

This page intentionally left blank