Early FM Radio

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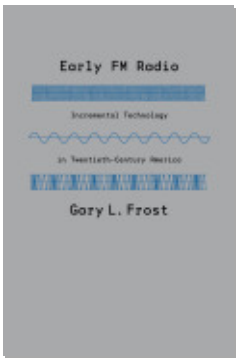

Published by Johns Hopkins University Press

What Do We Know about FM Radio?

> It isn't ignorance that causes the trouble in this world; it is the things that folks know that ain't so.
>
> *Edwin Howard Armstrong, quoting Josh Billings, 1944*

This book presents a clean break from the traditional history of frequency-modulation radio. Some readers will open this volume because they already know the canonical story of FM radio's origins, one of the twentieth century's iconic sagas of invention, heroism, and tragedy. Possibly they learned it from Ken Burns's 1992 documentary film, *Empire of the Air*, or from Lawrence Lessing's "definitive" 1956 biography of FM's inventor, *Edwin Howard Armstrong: Man of High Fidelity*.[1] In any event, all those who have written about the history of FM broadcasting tell more or less the same story: In 1933 the U.S. Patent Office issued patents to Armstrong for his system of "wideband" frequency-modulation radio. More than a decade earlier, everyone else had abandoned FM as impractical, but Armstrong's system astonished the world by suppressing static and reproducing sound with far greater fidelity than AM radio did. The Radio Corporation of America tested the Armstrong system and, after concluding that FM threatened its AM radio empire, RCA not only declined to develop frequency modulation but also tried to suppress it. Nevertheless, Armstrong persevered. Spending much of his personal fortune, he built an experimental broadcast station, which led to the Federal Communications Commission (FCC) establishing the first commercial FM broadcast service in 1940. Afterward, as part of a strategy to cripple FM, RCA refused to pay Armstrong royalties for his invention. In 1948 he sued RCA, a move that cost him far more than he could have expected. Finally, in early 1954,

as the trial dragged into its sixth year, a despondent, exhausted, and nearly broke Howard Armstrong took his own life.

Although this tale delivers great emotional power, it actually raises questions more important than the ones it answers. No historian has written more than a paragraph or two about the presumably unfruitful FM research that occurred before 1933, nor has anyone explained a glaring contradiction in the attitude of RCA's managers toward new radio technology during the 1930s: why, if they feared FM, did the firm invest so much during the same period in the far more revolutionary technology of television? We have no idea what steps Armstrong took in developing his system, leaving us at the mercy of facile invocations of Armstrong's "genius" to describe how he invented FM. And no historian has analyzed more than cursorily the patents and technical papers of Armstrong, let alone anyone else involved in FM research. To read the canonical history of FM radio is to explore not so much a history as a technological mythology that pits individualism against collectivism, the independent inventor against the malignant corporation, good against evil.

Today, a huge amount of archival material, scarcely examined since it became available nearly twenty years ago, makes possible a challenge to the canonical history. In 1990 the law firm that represented Armstrong donated his files to the Rare Books and Manuscripts Collection of Columbia University. Because Armstrong obtained a copy of every RCA document related to FM radio when he sued that company, these files—consisting of more than five hundred boxes and dozens of reels of microfilm—make up a complete archive of FM radio research before 1940 within the RCA organization. These documents reveal much that conflicts with the canonical history. For example, RCA and other companies did not give up on FM radio before 1933. Also, RCA did not so much fear FM radio during the 1930s as cultivate an indifference based on ignorance about the Armstrong system.

These documents make possible a fresh and much more careful examination of old sources. Recent historians of science and technology will recognize familiar elements in this book. It argues that FM emerged not so much from the mind of a single man but from a decades-long incremental and evolutionary process involving dozens of individuals. Scholars have shown that social-technological systems as complex as FM radio result from far more complicated processes than merely the straightforward application of laws of nature, and in the shaping of FM radio, nature was again only one factor. Because the development of a technology with even revolutionary potential often requires a long period of gestation before gaining momentum, any number of cultural, political, and com-

mercial interests can heatedly contest how natural laws are framed to make new technologies. Except in the narrowest sense, no one can determine the criteria of what constitutes the "best method" among several competing versions of the same complex technology.[2]

What Are AM and FM Radio?

During the twentieth century, two kinds of modulation dominated radio broadcasting: amplitude modulation (AM) and frequency modulation (FM).[3] They both begin with a continuous radio-frequency sine wave called a "carrier"—that is, a wave of constant amplitude and frequency that oscillates above approximately 100,000 cycles per second (cps).[4] Today, the FCC assigns to each licensed station in the United States a precise carrier frequency. An AM station, for example, might transmit its programs on a carrier frequency of, say, 700 kilocycles per second (700,000 cps). The commission regulates FM radio stations similarly but assigns them much higher carrier frequencies, currently between 88.2 and 107.8 megacycles per second.

FM and AM radio also differ in their means of carrying information. An unmodulated AM or FM transmitter conveys silence by radiating only its carrier wave. Modulation occurs when an audio wave—the electrical analogue of a sound wave—alters either the amplitude, frequency, or phase of the carrier. In the case of AM radio, a modulating audio wave causes the carrier to rise and fall in amplitude, thereby creating an "envelope" that replicates the shape of the original audio wave. By contrast, when an audio wave modulates an FM transmitter, the carrier's amplitude does not change; rather, the so-called instantaneous frequency of the carrier wave increases and decreases with the amplitude of the audio wave.[5] Thus, when the amplitude of the audio wave rises to its maximum positive level, the instantaneous frequency of the transmitted wave increases to a maximum limit. Conversely, when an audio wave descends to its most negative point, the transmitted wave decreases its instantaneous frequency to a minimum value. An audio signal with an amplitude between the minimum and maximum values alters the radio-frequency shift proportionally (see figs. 1, 2, and 3).

Finally, FM stations have substantially wider channel widths than typical AM stations do. A channel is the portion of the radio spectrum that any modulated radio signal requires to convey information. The FCC assigns each licensed AM station a carrier-wave frequency, with two 5-kilocycle "sidebands" on each side of the carrier, making up a 10-kilocycle-wide channel. AM station WLW in Cincinnati, for example, broadcasts a 700-kilocycle carrier but uses frequencies from

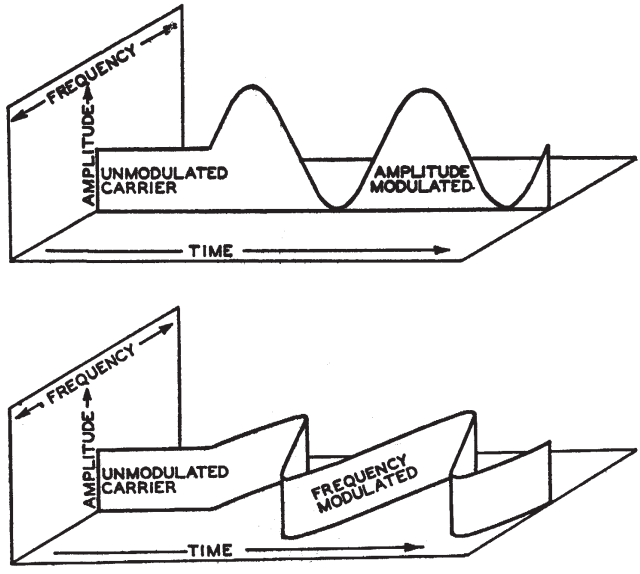

Fig. 1. Comparison of AM and FM Waves. In AM and FM alike, an unmodulated sinusoidal carrier wave radiates at a constant amplitude and frequency. With AM (*top*), modulation occurs when the amplitude of the carrier rises and falls according to the rise and fall of an audio wave. With FM (*bottom*), modulation occurs when the frequency of the carrier "swings" in proportion to the rise and fall of an audio wave. FM sidebands are not shown. Adapted from *The "Radio" Handbook*, 7th ed. (Santa Barbara, Calif.: Editors and Engineers, 1940), 214.

695 to 705 kilocycles to do its job. (To illustrate this arrangement, fig. 4 depicts five channels on the standard AM broadcast band.) By contrast, FM broadcasters use 200-kilocycle-wide channels because those stations effectively emit sidebands that extend 100 kilocycles above and below the carrier frequency.

The Canonical History of FM Radio and Individualist Ideology

Anyone who writes a history of FM radio must come to terms with that technology's canonical history. The narrative of FM radio's genesis, like FM radio itself, evolved from a predicament in which Howard Armstrong found himself during the mid-1930s. In 1934 and 1935 RCA tested his wideband FM system and opted not to purchase the patent rights. The firm never provided clear reasons for spurning FM radio, but this rejection fostered the impression that wideband

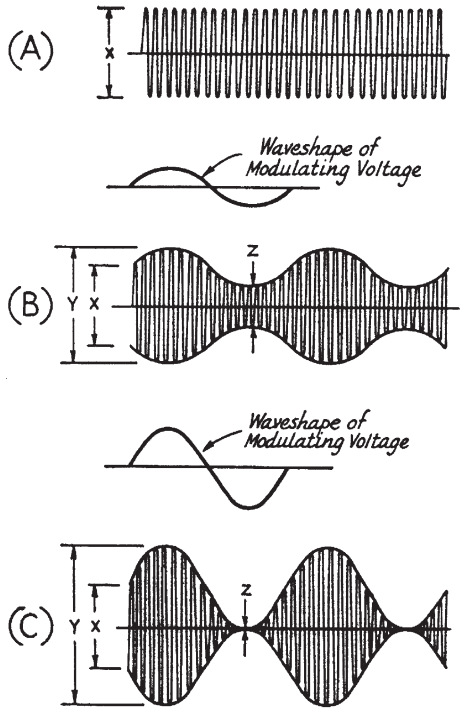

Fig. 2. Amplitude-Modulation Waves. AM radio waves on horizontal time scale: (A) the unmodulated radiofrequency carrier; (B) the carrier at 50 percent modulation; and (C) the carrier at 100 percent modulation. The outline of the modulating voltage is visible on the "envelope" of the modulated carrier waves. Adapted from Headquarters Staff of the American Radio Relay League, *The Radio Amateur's Handbook* (Hartford: American Radio Relay League, 1962), 284.

FM failed on technological grounds, for no other company at the time symbolized more the vibrant technological creativity and expertise that characterized radio. Armstrong and other FM pioneers worked up an alternative explanation in which economic reasons trumped technological ones. Frequency-modulation radio, they claimed, sprang fully developed from the mind of Edwin Howard Armstrong. RCA, which had nothing to do with the origins of Armstrong's invention, declined to back Armstrong out of fear that FM radio threatened RCA's huge capital investment in AM radio technology. For half a century, the boldest and most influential version of this narrative has resided in several chapters of Lawrence Lessing's hagiographic biography of Armstrong. Since then, virtually all historians of FM radio, and consequently anyone who reads about the his-

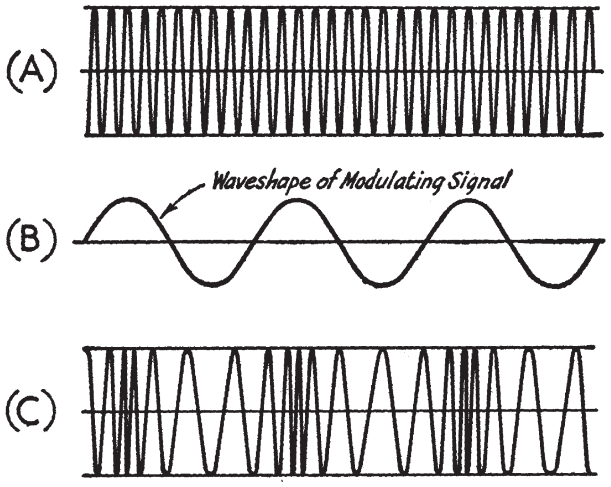

Fig. 3. Frequency-Modulation Waves. FM radio waves on horizontal time scale; (A) an unmodulated carrier; (B) the modulating wave, usually an audio program; and (C) a radiofrequency wave whose wavelength varies with the instantaneous amplitude of B—that is, as B rises and falls in amplitude, the frequency of A rises and falls correspondingly. Adapted from Headquarters Staff of the American Radio Relay League, *The Radio Amateur's Handbook* (Hartford: American Radio Relay League, 1962), 284

tory of frequency-modulation radio, will find himself or herself discoursing with Armstrong, chiefly through the words of Lawrence Lessing.

Lessing spins the invention of FM as a Cold War allegory—an individualist and anticorporate "great man" story, and the culminating episode in the life of a heroic inventor who, "with the pride, secrecy and shrewdness of a lone wolf," patented modern FM in 1933.[6] Armstrong, according to Lessing, represented an earlier period of history that cherished individualism as the cornerstone of American virtue and progress.

> His only faults sprang from his great virtue and strength of purpose. He was a man who would stand up and battle for principles as he saw them against the powers of the world, however formidable. This is becoming so rare a trait as to be prized above rubies. The self-directed individualist, combative, independent and free, who has been responsible for most of the great advances in human culture and invention, is a breed that is passing, at least in this generation and this glacial period of history.
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> There is, in fact, no one quite of Armstrong's large, individualistic stature left on the inventive scene.[7]

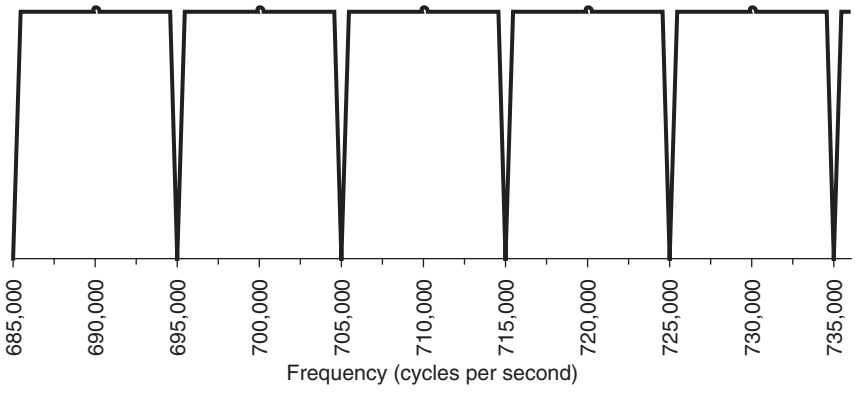

Fig. 4. AM Radio Channels. Depicted in this section of AM broadcast band spectrum are five complete channels and one partial one. Since the 1920s, the Federal Radio Commission and the Federal Communications Commission have allotted the range from approximately 550 to 1,500 kilocycles to broadcasting.

Tragically, he explains, big business interests forced Armstrong to spend the remainder of his life and much of his fortune in court defending his claim to FM as "his last brainchild."[8]

Armstrong's chief antagonist in this saga was the elephantine Radio Corporation of America, ruled "with plump Napoleonic force and immense vanity" by the wily David Sarnoff. RCA occupies a lower level than Armstrong does in Lessing's moral universe, largely because corporations are at best purveyors, not creators, of technological creativity. "It is only the stray, non-conforming individual, rubbing by chance and inclination against freely available knowledge who makes the great discoveries or inventions," he says. "Neither big research teams nor giant laboratories nor large research budgets can substitute for one creative mind. Every great product or development of modern industry may be traced to such independent individuals. Only rarely have they been found in the employ of industrial laboratories."[9]

Lessing reveals almost nothing about FM research before 1933, which seems to buttress his implication that "big research teams" and "giant laboratories" had nothing to do with the development of FM radio. Moreover, he describes RCA and David Sarnoff after that year as obstructing the development of frequency modulation. Fearing that FM might destroy RCA's AM-based empire, Sarnoff betrayed Armstrong—and by extension America—first by withholding RCA's financial backing for FM, then by attempting to "talk down" FM, and finally by trying to rob Armstrong of his claim to FM's invention. In 1948 Armstrong sued

RCA over the firm's refusal to pay royalties for using his FM patents. Delaying tactics on the part of RCA's lawyers prolonged the litigation for six years, which led to tragedy. On the night of 31 January 1954, Howard Armstrong—"at the end of his rope"—stepped to his death from the window of his thirteenth-floor New York City apartment.[10]

Regrettably, the authority accorded to *Man of High Fidelity*, which was published two years after Armstrong's suicide, speaks more to the absence of research since 1956 than to the quality and scope of Lessing's scholarship. To be fair, Lessing frames a nuanced argument that incorporates plausible contextualist themes. Much of his book situates Armstrong amid social and economic forces that few historians today would deny, such as the dramatic growth of corporate research and economic power in the early twentieth century. But Lessing's book, engagingly written for a general readership, discusses sources only sporadically and even admits to bias. The foreword to the first edition describes *Man of High Fidelity* not as a history of FM but rather a "partisan [biography] with respect to the man, whom the author as a journalist knew over a period of fifteen years and esteemed as a great man."[11]

Despite these shortcomings, Lessing's influence on subsequent histories of FM cannot be overstated. Only one historian has used other, mostly primary, sources, to refute a small part of Lessing's version.[12] More typically, the only book-length history of FM published before 2008 cites *Man of High Fidelity* more than any other source, and virtually every radio history Web site recommends the book to visitors curious about FM's origins.[13] Lessing's interpretation has seeped into even the most distinguished scholarship. Thomas Hughes's *American Genesis*, Tom Lewis's *Empire of the Air*, and Susan Douglas's *Listening In* all depend heavily on Lessing.[14] Even Christopher Sterling and Michael Keith, whose recently published book, *Sounds of Change,* constitutes the best general history of FM radio broadcasting, stay close to Lessing's interpretation when examining the prewar period.[15] Indeed, with little else written about the subject, how could they not?

Methodology

This book follows an approach that borrows from scholarship of the past three decades. For several years historians of technology have been classified by how much or little they choose to emphasize the material aspects of their subject. At one end of the spectrum are "internalists" who, as John Staudenmaier writes, "converse with a narrowly defined group of scholars who have made the technology in question their primary concern." Somewhat derisively and unfairly

called "gear fondlers"—or "tube fondlers," in the case of radio history buffs—internalists tend to focus almost exclusively and often meticulously on the "nuts and bolts" of their subject. The polar opposites of this group are "externalists," who are "interested in cultural context, [and] pay almost no attention to issues of technological design." Because I find great value in both approaches, this study adopts a middle-ground "contextualist" approach, which, as Staudenmaier explains, "attempt[s] to integrate a technology's design characteristics with the complexities of its historical ambience."[16]

This study also takes what has variously been described as a moderate social-constructivist or socially shaped perspective. Social constructivists renounce historical interpretations based on technological determinism as simplistic. That is, they see technology not only as an explanation for history but also, and more often, as something to be *explained by* historical forces.[17] Accordingly, this book argues that cultural, organizational, economic, and other contingent "social" factors strongly shaped the design of broadcast FM radio at every step. To be sure, technology, including radio, has exerted tremendous influences on society. But social constructivist histories look beyond a one-dimensional "technology-drives-history" perspective, seeking the social factors that influence historical actors to make choices that lead to the development of certain technologies. Therefore, this study takes, in the words of Thomas Hughes, a more or less "seamless web" approach toward its subject, in which the hardware of the technology is both cause and effect in the historical narrative.[18] One can neither remove the social from the technological side of FM's history nor remove the technological from the social.

This is not to say that FM was entirely socially constructed, with the natural world having no say in the matter, but only that no one "discovered" FM in the same way that William Herschel discovered the planet Uranus or Glenn Seaborg discovered plutonium. This study tells not so much a history of the "construction" of a technology as a "shaping" of a technology, because readers might infer from the word "construction" that the natural world plays no role in how any technology is interpreted.[19] On the contrary, making complex new technological systems resembles collective artistic creativity more than scientific discovery. Each member of a group of sculptors can take a turn at chiseling a block of marble to "reveal" the statue underneath. Every artist—every group of artists—will "find" a different figure but must do so within two constraints, one contingent and flexible—human imagination—and the other mercilessly rigid, namely, the marble's natural properties. Invention also must comply with laws of nature, some of which are imperfectly understood, or even unknown, but those

laws rarely restrict the process of developing new technology sufficiently to allow anyone to predetermine the outcome. Thus, FM has come in innumerable forms, only one of which makes up modern broadcast FM, which itself differs significantly from what Armstrong's 1933 patents described. In other words, the invention and development of FM followed a trajectory constrained by the natural limits of the material world, planned research, and happenstance.

Finally, this study will delve into the technical details of radio. The economic historian Nathan Rosenberg has written that "the social and economic history of technology can only be properly written by people possessing a close familiarity with the actual technology itself."[20] Fortunately, this book demands far less from the reader, who will, with patience, nevertheless learn a little about how radio works. Novices to the field should take comfort in the fact that much of the technology itself was literally child's play. After the crystal detector was patented in 1906, the ranks of amateur radio operators swelled with hundreds of thousands of boys (and more than a few girls).[21] The apparatus they "worked" was largely composed of simple hardware: wires, condensers, transformers, and insulating materials, for example. Assembling these components into a radio set was a creative process, but not an illogical or an especially complex one. True, a schematic drawing of an early radio transmitter or receiver could baffle anyone entirely untrained in circuit theory, but with a little effort, young practitioners learned that becoming an expert chiefly required comprehending a few rules about a few electrical components. Still, this study does not assume that its readers have reached the same level of technical expertise as the child hobbyists of a century past and will from time to time translate "texts" of early twentieth-century radio technology that appeared in patents, published technical papers, and personal correspondence.

A Note about Terminology

Decades of imprecise terminology have muddled FM radio's history. Traditionally, the system for which Armstrong was awarded patents in December 1933, and on which modern broadcast FM has been based since 1940, has been called both *Armstrong FM*, and *wideband FM*. The usage of wideband FM has fostered the inference that previous, presumably failed, FM systems were narrowband FM, a term that suggests a channel width narrower than a standard 10,000 cps AM band. I am forced to employ the term wideband FM, but I also emphasize that only a negligible proportion of FM research ever targeted a channel narrower than 10,000 cps.

TABLE 1
Categories of FM Radiotelephony

Ehret FM (1902)
Existed only in two patents issued to Cornelius Ehret. Spark gap transmitter with slope detector receiver. Unworkable.
Narrowband FM (early to mid-1920s)
Channel width: 10,000 cps or less. Determined to be theoretically unworkable in 1922, although the U.S. Patent Office later issued four narrowband FM patents.
Armstrong wideband FM (patents filed January 1933)
Armstrong low-tube-hiss FM (January 1933–Spring 1934)
Described in Armstrong patents of 26 December 1933 as a system for the reduction of tube hiss. Frequency swing: 150,000 cps. Armstrong originally declared that his invention had no effect on static.
Armstrong low-static FM (Spring 1934–)
Essentially the same technology as low-tube-hiss FM but reinterpreted. During the spring of 1934, Armstrong learned that, contrary to what he had claimed in his patents, his invention reduced static dramatically.
Armstrong high-fidelity FM (late 1937–)
Low-static FM after Armstrong began incorporating high-fidelity audio circuits into his low-static system. Audio bandwidth was an unprecedented 15,000 cps. Functionally equivalent to modern monophonic broadcast FM radio.
All other frequency-modulation and phase-modulation systems (1920s–)
All other FMs, both before and after the invention of Armstrong wideband FM. Channel widths ranged between 10 and 30 kilocycles.

Moreover, the terms Armstrong FM and wideband FM falsely imply a non-existent stability for the technology. In fact, Armstrong's understanding of what he had made changed significantly during the period from 1933, the year he filed his most important FM patents, and 1940, when the FCC established a new FM broadcast radio service. For that reason, I use Armstrong FM (and wideband FM) only as general terms for the invention for which he was awarded patents in December 1933 and which continued to evolve afterward. But I also use *low-tube-hiss FM*, *low-static FM*, and *high-fidelity FM* to refer to Armstrong FM at three stages of its development during the mid- and late 1930s (table 1).

Finally, the reader should note that this book conforms to a convention of the period it covers by not using the modern unit of frequency, the Hertz. Instead, frequency is measured, as it was before 1960, with one of the following units: cycles per second (cps) or cycles; kilocycles per second (kps) or kilocycles; or megacycles per second or megacycles (mc).