A History of Engineering and Science in the Bell System

The Early Years (1875–1925)

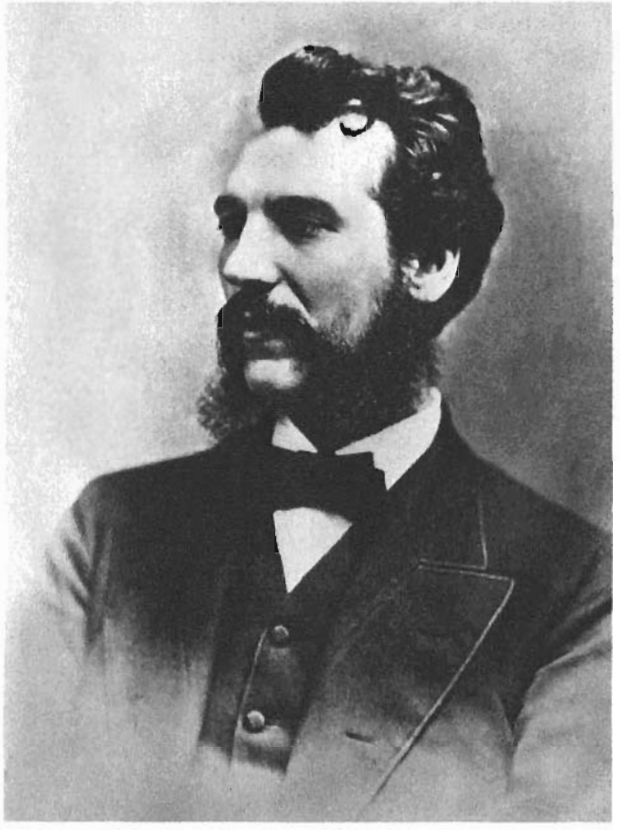
A History of Engineering and Science in the Bell System: The Early Years (1875–1925) offers a detailed view of the first fifty years of telephone technology. The narrative goes well beyond a simple statement of events to deal with the "how" and "why" of technological innovation. It examines the underlying motivations and evaluates the long-term importance of the engineering, scientific, and organizational achievements that were the substance of the first five decades of remarkable progress in telecommunications. While this technical history is primarily an account of Bell System achievements, the treatment has not been constrained by corporate boundaries and thus recognizes fundamental contributions originating outside of the System.

During the half-century covered by *The Early Years*, a whole new field of technology evolved. Starting in 1875 with Alexander Graham Bell and Thomas Watson, a small group of prolific inventors, with little theory or practice to guide them, set out to develop a communication system that, unlike the telegraph of the time, could be used by anyone. Bell's vision, however, far transcended the first primitive steps in telephony and quite early he outlined his "Grand System" for a worldwide network designed to interconnect any two users for voice communication wherever they might be. This concept has served as the broad telephonic objective ever since both within and outside of the Bell System.

The opening chapter of *The Early Years* relates the events leading up to Bell's conceiving his "Grand System"; subsequent chapters deal with developments in specific areas of technology that led towards its realization. The evolution of station apparatus, wire and wireless (radio) transmission, switching, and various non-voice services is described in detail. Other chapters cover the development of materials and components for these new communications systems, the origins of quality control techniques, and the beginnings of scientific research in the Bell System. An early chapter is devoted to the corporate structures of the period since these organizational arrangements provided a continuing synergy of business planning and advancing technological skills.

A History of Engineering and Science in the Bell System: The Early Years (1875–1925) is illustrated with over 500 photographs and drawings taken from Bell System historical collections or prepared especially for this volume. A carefully selected list of references and a comprehensive index also are provided.

A number of members of the Technical Staff at Bell Telephone Laboratories, both active and retired, participated in the planning, historical research, writing, and review of the material in this technical history; other members provided personal recollections or prepared source documents. The editor, M. D. Fagen, is Director, Special Projects, in the Information and Publication Division. The volume was prepared for publication by the Technical Publication Department of Bell Laboratories.



". . . Not only so, but, I believe, in the future, wires will unite the head offices of the Telephone Company in different cities and a man in one part of the country may communicate by word of mouth with another in a distant place."

Alexander Graham Bell

A History of Engineering and Science in the Bell System

The Early Years (1875–1925)

Prepared by Members of the Technical Staff,
Bell Telephone Laboratories.
M. D. Fagen, Editor.

Bell Telephone Laboratories, Incorporated

Credits for figures taken from
other than Bell System sources
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in 1876. Photograph by E. A. Holton,
The Bell Family © National Geographic Society.

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Foreword

The years 1974 to 1976 mark the first century of Alexander Graham Bell's invention and development of the telephone. The basic principle on which the telephone operates—the idea of an undulating current, the analog of a sound wave—was conceived in the summer of 1874 but not until a year later were sounds of a speech-like character heard over wires. On February 14, 1876, Bell applied for his first patent, which was granted on March 7. On the evening of March 10, he transmitted the first intelligible sentence. Many demonstrations of the new invention were conducted, probably none with so great an impact on the public feelings as that held in Philadelphia during the summer of 1876 at the exposition celebrating the centennial of American independence. This bicentennial year of our nation's independence therefore seems particularly appropriate for publishing a history of telephone communication, the growth of which has been so closely associated with the second century of our country's development.

This first volume of a series on the science and technology of telephony covers the half-century following Bell's invention. By the end of that time a great new industry had been developed. There were nearly seventeen million telephones in the United States, almost twelve million of them in the Bell System. And in perhaps no other field had the force of scientific research in support of engineering development been so effectively demonstrated.

The year 1975 marks another anniversary, the fiftieth year of the establishment of Bell Laboratories as the research and development unit for the Bell System. In 1925, it became a corporate entity, sharing responsibility with the Western Electric Company, the American Telephone and Telegraph Company, and the System's 24 Operating Telephone Companies for providing nationwide communications services and for planning, engineering, building, and operating the nationwide network.

The formal incorporation of Bell Laboratories was not a beginning of scientific research and engineering in the Bell System, but rather a stage in its growth in a line going back to Alexander Graham Bell's original laboratory in Boston. In 1907, a consolidation of the engineering forces took place in the Western Electric Company and in AT&TCo. As stated in 1925 by Mr. H. B. Thayer, then President of AT&TCo:

> The reorganization in 1907 consisted of a consolidation [whose] purpose was to avoid duplication of facilities as well as to get the greater efficiency coming from a closer contact between the staff of the Western Electric Company and our own. [He meant AT&TCo.] It brought to one point scientific study and research, manufacturing experience and operating ex-

> perience . . . It simplified and expedited the work of the operating [telephone] companies in that it established one point where all statements of requirements, suggestions of improvements, or criticisms arising out of their operating experience could be considered and discussed from all points of view . . . It was helpful in the standardization of apparatus . . .
>
> We had at the West Street laboratory (headquarters of the Western Electric Engineering Department) the scientists whose work involved laboratory facilities, the men conducting experiments, the shop design workers and the inspectors with suitable equipment of laboratories and model shops available for all. The ideas of our research and development scientists and engineers, worked out on paper or in rough mechanical form, were there developed into a finished piece for shop manufacture and after manufacture the product was then subjected to all the tests necessary to satisfy our engineers that it was worthy of introduction into or continuation in the plant of the Bell System.

This indicates clearly the important evolution in research and development management taking place in the Bell System early in the twentieth century. But as Thayer explains subsequently in the same article, it became evident by the early 1920s that even greater benefits could be expected by further centralizing research and development in a new organization, Bell Laboratories, working closely with the producers and users of communication systems:

> Now the time has come when, it seems, we can take another step forward with advantage. What was contemplated in the reorganization of 1907 has been entirely accomplished, in that the development, research, and experimental work of the entire Bell System has been coordinated and has been concentrated as far as is desirable. The standardization of material is in effective operation. The different organizations composing the Bell System are working efficiently and harmoniously as parts of the greater organization, but this seems to be the time to get still more of the advantages in efficiency and economy which the consolidated organization now proposed makes possible.

This statement is an expression of what we have come to recognize as enduring themes in the maturation of technology in our business. First, there is reference to the economy and efficiency which comes through centralization of engineering and the standardization of systems which are meant to work together. Technical advance must be planned and orderly.

Second, there is the emphasis on technical integration, the need for intimate contact among the engineers and scientists working on all phases of a problem, extending from initial studies to the complexities of manufacture, installation, and use. And the latter specifically calls for close association of planners, designers, and the manufacturer with the operating entities of the organization.

Third, there is the emphasis on "scientific study and research," an idea which was quite new to industry in the early years of this century. The Bell System was one of a very few industrial organizations in which professionally trained scientists were doing basic research

on fundamental problems related to company objectives. The experience of the intervening years has affirmed this belief in the values of research many times over, as, indeed, this history of communications will attest.

Finally, there is the important concept that our engineering and science through design, development, and manufacture be responsive to the needs of the final users—the Operating Telephone Companies who provide communication services to the public—and that innovations be "worthy of introduction into . . . the Bell System." The integrating influence of this ever-present goal—providing good telephone service to the ultimate consumer—has in a very real way tied together all the elements of the creative process throughout the Bell System over the 100 years of our history. We have no need to cite examples in this Foreword; the contents of this volume will do that in what I believe to be a most convincing fashion—by narration of a succession of technical triumphs unique in the history of industrial technology—producing what is generally acknowledged to be the most capable communications system in the entire world.

There is much to be learned here, as lessons from the past, true today as they were in the period 1875–1925, about the process of innovation as it really is. It was characterized then, as it is now, by continuity of technical activity from basic discoveries and inventions to direct operation in the communications network. We learned then and we know now, with a conviction born of experience, that conversion of new ideas, devices, and systems into something actually usable is a subtly demanding, personalized undertaking. The new concepts must be technically feasible and economically sound, they must fit into an existing operating plant, they must satisfy a real service need, they must be reliable and maintainable over a useful life of decades. And our long experience has demonstrated that this difficult task is unquestionably accomplished most effectively by the integration of technology through design, manufacture, and operation. In our semicentennial year, our intimate, daily associations with AT&TCo and Western Electric are at new, unsurpassed strengths.

Imbedded in the reality of technological innovation, but perhaps not as readily apparent as some of its other features, is the ever-present competition of ideas and approaches which exists in a large integrated structure such as ours. And it is the competition of ideas, rather than the competition of an undefined and arbitrary market place, that is the spur which really leads to technological progress. The reader of this volume will see it illustrated in the search by George Campbell for a better transmission line. He will see it a little later in the search by H. D. Arnold for an amplifier to implement the drive of T. N. Vail and John Carty for transcontinental telephone service; in the search by G. W. Elmen for a superior magnetic material for coils and transformers; in the quest by W. G. Houskeeper for a better glass-to-metal seal for high-power radio transmitting tubes that could generate the waves to carry the voice across the ocean.

It was the competition of ideas that stimulated their colleagues to press ahead, inventing oscillators, modulators, and wave filters that would permit the multiplexing of many conversations over a single circuit. And it was the same motivation that led to transmission of television signals by wire and radio over long distances, and to explanations of phenomena as fundamental as the complementary behavior of electrons and waves—a study which resulted in the award of the Nobel prize to C. J. Davisson.

There was a strong motivation then, as there is to this day, toward a well-defined goal—defined by the nature of the environment in which the work was done and by the searching spirit in a talented assemblage of technical experts who knew that what they were doing was relevant and what they produced would be useful.

In this, the hundredth year of the Bell System and the fiftieth year of Bell Laboratories, our modern world of communication is a world made up increasingly of digital signals and computers, of microwave radio and coaxial cable transmission systems, of satellites and broadband transoceanic cables, of electronic switching systems of unprecedented speed and versatility employing millions of transistor-like devices of microscopic dimensions. In the times ahead, we see millimeter waveguides, and optical fibers with capacities for conveying information at rates thousands of times greater than we know today, and especially automata enabling efficiencies and services making telecommunications a still greater frontier of human progress.

Those whose accomplishments are described in this volume could not foresee these things in detail, but they laid down the principles. It is clearly evident to us that the enduring themes in communication technology have not changed. Our incentives for acquiring new knowledge and our techniques for applying that knowledge to practical ends to satisfy human needs were right for our first fifty years and offer yet stronger opportunities for our latter fifty. Thus, this history is more than a mere record of past events. It provides an insight into the process of innovation and effective application of technology for beneficial purposes. Finally, it clearly demonstrates the intimate connection between the successes achieved by Bell System Operating Companies and the integrated structure they support for providing technological innovation, manufacture, and field application.

W. O. Baker

President,
Bell Telephone Laboratories

Acknowledgments

This volume is the work of many minds and hands, members of the Technical Staff of Bell Laboratories whose experience in communications research and engineering, going back more than 50 years, included personal acquaintance with outstanding individuals who went before them, as well as thorough knowledge of their published records.

The material in these pages was written by experts in their fields, individuals of proven technical competence who were, at the same time, in positions of administrative responsibility for planning and completion of technical projects. Thus it has been possible to achieve an account that goes beyond the simple narration of events and to deal with the "how" and "why," searching out the motivations and evaluating the long-range importance of the contributions to communication technology which are the substance of this history.

This is primarily an account of early Bell System achievements, but the authors have not been restricted by geographic or corporate boundaries and have recognized fundamental contributions originating outside the System. Nor has the treatment been constrained by strict time boundaries, since many programs initiated before 1925 were continued in the years following. Moreover, from our present position in the 1970s we can see, in retrospect, the formative stages of new ideas that were to have tremendous impact over long periods after 1925, some being even today the very essence of telecommunications.

Where outstanding developments and discoveries are clearly attributable to an individual, we have tried to give appropriate credit. The selection of a group of names is done with reluctance since others may well deserve equal mention. It is understandably impossible to list the hundreds who participated in the team effort responsible for so much of the technical advance made during these 50 years. We acknowledge the great debt owed to those dedicated workers whose creativeness, enthusiasm, and unselfish exchange of ideas with their fellows contributed so much to building up a completely new field of technology.

This history was initiated at the suggestion of James B. Fisk when he was President of Bell Laboratories. Most of the writing is the work of W. H. Doherty (Chapters 1, 2, and 10), and J. W. Emling (Chapters 3, 4, 5, and 6), both of whom also collaborated in the planning of the volume. The Non-Voice Communications chapter was prepared by F. J. Singer, the Materials and Components chapter is largely based on material submitted by A. G. Ganz and M. C. Wooley, and the Quality

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There are those who should be recognized for their part in producing the printed work: Miss R. L. Stumm, who worked tirelessly

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M. D. Fagen
Editor

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