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COMMUNICATION ENGINEERING[1]

By Dr. FRANK B. JEWETT

BELL TELEPHONE LABORATORIES

IN most respects the history of electrical communication and of the engineering on which it rests is typical of the history of all great modern industries based on science and which did not originate in the unrecorded and presumably accidental experiences of our remote primitive ancestors. The development of electrical communication in all its branches discloses the typical sequence of one or more phenomena disclosed by fundamental science research appealing to a man or men with some understanding of science and possessed of the inventor's imagination and urge to create new things of practical utility. Once the trail is blazed there follow in succession the eras of development, first by other inventors, then by engineers who know more of science than the inventors but who rarely create essentially new knowledge, and finally the era in which development is mainly in the hands of research men and engineers working in intimate cooperation.

All branches of electrical communication—land line and submarine cable telegraphy, radio transmission, whether for telegraphy or telephony, and telephony by whatever means the signal impulses are transmitted or for whatever purposes employed—have gone through the several cycles. Further, they have spread out in this last era to embrace the art of permanent recording and subsequent reproduction of sound and much of the field of acoustics. In all these fields the major advances in the future over the present art are to be looked for in the research laboratory. Mainly I surmise these advances will emanate from the industrial research laboratory, although in the future, as in the past, revolutionary concepts are likely to originate in the laboratories of fundamental science and be brought to fruition in those of industry.

All forms of electrical communication are at base

[1] Address delivered at the symposium on recent progress of science in connection with the dedication exercises of the new building of Mellon Institute, Pittsburgh, May 7, 1937.

variant offshoots of common root stock. All require terminal apparatus to transform signal impulses into electrical impulses or the reverse; all require some form of conducting medium for these electrical impulses, either guided as in the case of wire transmission or broadcast as in radio, and all to a greater or less degree employ switching mechanisms, either manual or automatic.

Due to the nature of the impulses it must manipulate; to the necessity for simultaneous two-way transmission; to that of essentially instantaneous establishment on demand of connection in any random fashion between any two of an enormous number of terminal stations and because of the sheer magnitude in number of these connections made each day, the scientific and engineering problems of telephony are far greater and more complex than those of all other branches of electrical communication put together. Further, solution of problems in telephony rather automatically solve many problems in the less general cases which arise in the other branches.

Because of these facts and since the time available in this symposium is limited, I shall confine discussion to the field of two-way telephony as being typical and to a large extent though not wholly inclusive of the other fields of electrical communication.

About thirty years ago it became increasingly apparent that telephone development had outrun the possibility of large future advance wholly under the guidance of the inventor and engineer. The problems ahead, whether of terminal apparatus, transmission, switching or of economics, were such as to demand the attention of men thoroughly acquainted not only with current advances in the basic physical sciences but likewise with the powerful methods of investigation which were producing new knowledge. The urgency of many of the problems made it imperative both that all existing knowledge be scrutinized and employed when available and that new leads be developed more rapidly than was to be anticipated from the unorganized attack of individual investigators.

It was from the necessity of this situation that the beginning of industrial research as we now know it began in the field of electrical communication. Progress was slow at first, partly because it was a radically new approach little understood by those who had carried on successfully the previous development work and who were naturally skeptical; partly because it was difficult to know where and how best to start the attack, and largely because there were then very few suitable trained men available. Initially, judged by present-day criteria, much of the work, although scientific, was rather gross. Partly this was due to the nature of the existing structure on which we had to operate. Largely it was due to an almost complete absence of proper tools and techniques with which to work. The present-day research man in a well-equipped communication laboratory can have little conception of the difficulties which confronted his predecessors in their attempts to solve high frequency problems without any high frequency generators, shielded bridges, unbalance sets, amplifiers or the hundred and one other laboratory tools which are now the commonplaces of everyday use. Actually for many years in the early days of research laboratory development a large part of the time and effort of the staff was devoted to the creation of investigating and measuring tools.

Gradually, but with accelerated speed, the picture changed until now the research laboratory is fully recognized in the communication field to be the center from which come not only the advances in the art but also the basis for the engineering and operation of the new things it creates and the new methods it evolves. Subtract all or even a substantial part of the research laboratory and progress in communication would not only stop but the art would tend to retrograde and service to deteriorate. Present-day electrical communication is so completely a thing of intensely applied science and is pressing so closely on each new discovery in fundamental science in certain fields that it can only exist serviceably in an expanding world through continued application of the methods which have brought it into existence.

Parallel with the growth of the research laboratory and with its increasing power to solve difficult problems, to expedite the utilization of each new piece of knowledge and to produce new things, methods or services has been an expansion of the fields of science into which its energies have been directed. Each advance has added to the possibility of still further advances and to the necessity for greater nicety in making those advances. Any major problem to-day is certain to require consideration of a wide variety of matters in the field of the physical and mathematical sciences and not infrequently of the biological as well. Hence we find a large amount of research work going on which at first sight seems to have little if any relation to electrical communication.

This tendency to expand the area of research interest and attack seems destined to continue. Already a very intricate and delicate structure, the telephone plant is becoming each day more intricate and delicate as it grows in size and diminishes in unit fundamental cost. Each day the premium on integrity of operation increases and the importance of having full knowledge of every factor which can affect that integrity is enhanced. The telephone plant is a vast completely integrated structure designed for but a single thing, namely, to provide a reliable service for the most intangible thing in the world—the transmission of human thought. Being vast and completely integrated insignificant failures which elsewhere would at worst produce only moderate localized dislocation may here create disruption and disorder in distant places. A slowly acting but unsuspected chemical or physical reaction which in time will produce corrosion or disintegration of a vital contact or the failure of a crucial vacuum tube filament may throw into confusion a large part of the traffic over some important route or interrupt service across a continent or between continents.

It is because of this integration and complexity, combined with the magnitude of the multipliers involved, that research work in telephony is elaborate and conservative to an extent seldom if ever required elsewhere. Nothing of importance is ever standardized for general use in the telephone plant of the Bell System until it has undergone every laboratory test (including extensive service trial installations) which the ingenuity of trained scientists and engineers can devise. The penalties of failure are too great to do otherwise—we *must* know everything that present scientific knowledge enables us to know about each element of a new structure or system that is likely to affect operation during its service life.

There is no scintilla of doubt that our present electrical communication systems owe their existence to the research laboratory and to the engineering based on its work. Much of what they comprise could never have come into existence at all without the aid of highly organized industrial research laboratories. As for the rest, which was the art before they came into being, the costs incident to rising material and labor prices and to the inherent increase of cost with size in a telephone plant would have greatly limited growth. Thanks to the research laboratory we have thus far been able to offset these factors and it continues to be our hope for the future.

Now, in conclusion, a very brief survey of our present situation and of what the future seems to hold in store for communication research and engineering. The forward picture is quite different from what it was a few years ago when there were still geographical distances to be conquered or types of service which could not be given for lack of physical means.

The ultimate goal of telephone service is to give substantially instantaneous connection on every random demand, over a plant that is as nearly as possible 100 per cent. reliable and of essentially perfect transmission quality and at a cost which will insure maximum use—all within the limits of that financial safety without which no adequate service can be guaranteed or even provided. With no barrier of terrestrial distance now existing which can not in some fashion be spanned by telephone channels if need arises, and with every major element which controls the giving of random two-way telephone service at least partially developed, the problems of research and engineering in the years ahead are essentially the problems of a better cultivation of the entire field, to the end that the ideal goal can be more nearly attained.

If essentially instantaneous compliance with the random demands of millions of subscribers for telephone connections is to be met it means that the telephone plant must be adequate to handle the offered service at times of peak desire. Since the need and desire to telephone is controlled by the normal necessities of life and the established business and social habits of people and not by those who provide the means for rendering service, and since experience has shown that the periods of peak demand occupy but a limited portion of each twenty-four hours, any approach to the ideal means inevitably a provision of plant so profuse that a very large part of it must be idle a majority of the time. Such a condition can only obtain within those limits of reasonable cost which will insure maximum availability to those who would employ the service if the inherent unit costs of the plant are low. In other words, the conditions require that many elements must be provided at a cost not greater than that which could be justified for a single element which would be capable of handling all the traffic if this traffic were substantially uniformly distributed throughout the entire twenty-four hours.

As a result of the work thus far done in the research laboratory substantial progress toward the attainment of the ideal has already been made. Further, if additional progress is to be made the research laboratory is practically the only place to which we can look for the facilities and methods which will be required. There is every present reason to believe that continuation of organized research work along the lines which have proven so fruitful in the past can be depended upon to carry us a long distance beyond where we now are. This continuation will require an increasing amount of attention to details whose influence and effect in a less developed state of the art are masked by grosser limitations.

Merely by way of illustration, since somewhat corresponding examples can be selected from almost any area, I would call your attention to what concentrated organized research has thus far done and is now doing in the direction of providing transmission channels in profusion.

Without going back to the time when open wires on poles with one pair of wires for each channel were substantially the only means available for connecting subscribers together, we are but little removed from the time when, whether as open wires or as pairs of wires in cables, an actual physical circuit had to be provided for every connection that was made. The advent and development of loading coils and amplifying devices, both products of the laboratory, did not alter this necessity, although they did increase the distance over which communications could be given economically.

Until fundamental science, much of it involving new knowledge, was, through the coordinated work of industrial research, directed to the problem of extremely low-cost channel provision, there was essentially only one known way of providing a multitude of non-interfering channels along a common route. This was to assume that the electrical impulses over each channel were essentially alike and by means of geometrical and mechanical arrangement to reduce to a minimum the deleterious effects of transfer of energy from any circuit to its neighbors.

Recently, however, thanks to the research laboratory, operating in a myriad of fields and with organized utilization of the results in these fields, an entirely different method of providing large numbers of channels has been achieved and the way opened to an unknown indefinite extension. There is no time here to elaborate the niceties of the method. It is sufficient to say that it is what has commonly come to be designated as the carrier method, by which a single physical circuit can be made to transmit simultaneously a large number of non-interfering conversations by means of apparatus which is relatively simple and reliable and whose cost when apportioned among the several channels provides these channels much more economically than was possible under the older art. While there are definite limitations in the field of use of this method, it bids fair to have wide application over the longer distances. In its most advanced application, namely, that of the so-called coaxial cable, which is now undergoing trial in an experimental installation between New York and Philadelphia, many hundred telephone conversations can be carried on over a single pair of physical channels.

Achievement of this and similar less spectacular results imposes a burden of extreme nicety and reliability on the functioning of many devices, since failure of any one will disrupt not a single conversation but a multitude of conversations. That such multiple transmission can even be contemplated seriously is high tribute to the power of scientific research which makes it possible.

Broadly speaking, the main emphasis of all research in the telephone field is directed toward the goal of producing terminal apparatus, switching mechanisms and channels of communication of great reliability and minimum cost, both first cost and cost of operation and maintenance—all to the end that facilities can be provided in the profusion needed for a uniform no-delay service at an expense to the subscriber which will have minimum tendency to restrict usage where telephony is the indicated preferred method of communication.

In two of the main sectors, namely, those of switching and trunk channels as between central offices or between cities, the purely technical problems of unit cost reduction are frequently made somewhat easier by the fact that certain of the elements lend themselves to wholesale treatment. In much of the third sector, however, namely, that of local distribution to the subscriber, the case is essentially one of dealing with a retail problem. Here, even if the equipment itself and the channel connecting it to the central office could be furnished at extremely low cost, there would still be a substantial item of investment involved in the fact that installation and maintenance cost would be relatively high. Even here, however, it is to the research laboratory that we must look for most of such help as it is to be anticipated.

EARLY WORK ON INSULIN[1]

By F. G. BANTING, M.D.
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I first wish to thank the Mellon Institute for their kind invitation to be present on this occasion. I wish also to congratulate you on this fine new research laboratory. It is a monument to the Mellon family and also a monument to the successful work of the institute in the past.

Although I have heard much of the Mellon Institute it was not until I read the book of your director that I understood the true significance and scope of your endeavors. May I express the hope that your future activities will be crowned with equal or even greater achievement.

It was with great pleasure that I observed that the Mellon Institute is including in its activities certain problems in medical research. It is to be hoped that you will undertake research on other major problems in medicine and that you may even organize an attack on cancer.

The field of medical research is so wide that it is necessary to specialize. I did not therefore feel that I could adequately cover the field of internal secretions,

[1] Address delivered at the symposium on recent progress of science in connection with the dedication exercises of Mellon Institute, Pittsburgh, Pa., on May 7, 1937.