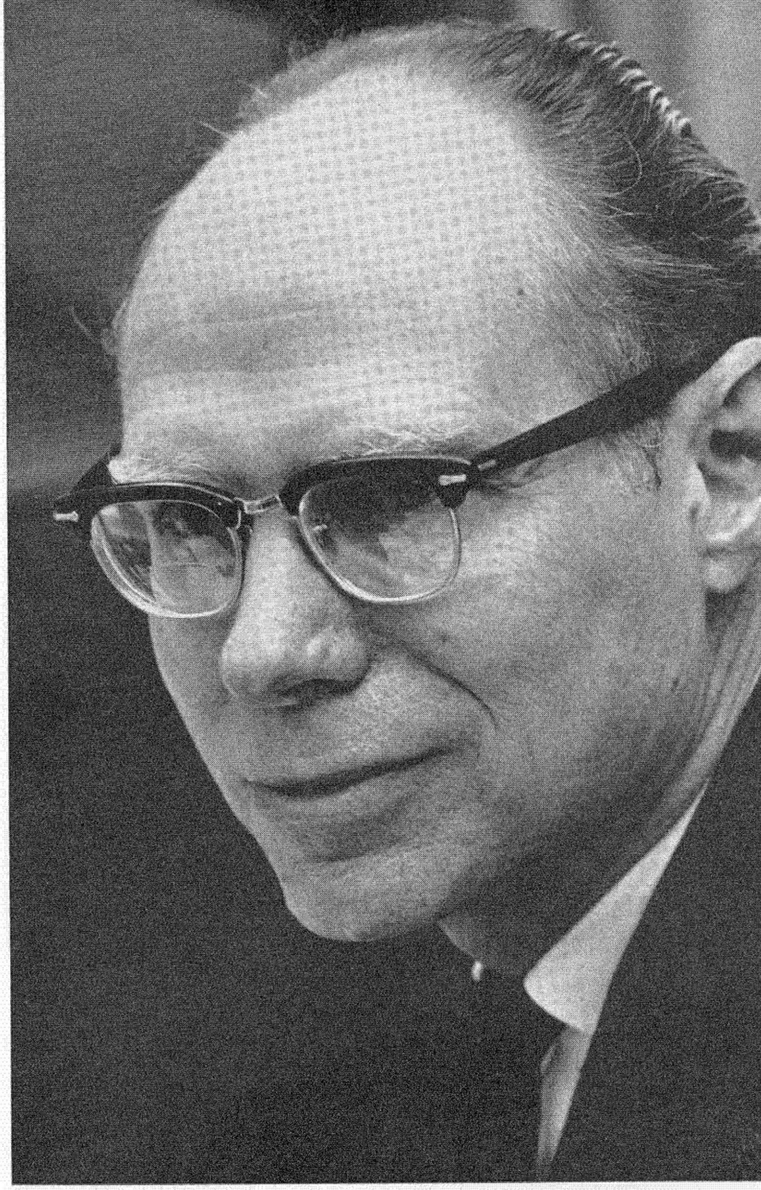
COMMUNICATION – OUTLOOK FOR THE FUTURE

by John R. Pierce



Modern electronic inventions have profoundly altered our lives, but in one way they have not altered the way in which we live. Today's child accepts the telephone and television with the same sense of familiarity and lack of understanding that earlier generations accorded natural phenomena. We do not need to know the physical basis of telephony in order to use a telephone any more than we need to understand the biological intricacies of a horse in order to ride one.

This sort of understanding is powerful in our world, but it is rare in connection with any common thing that is not a product of science and technology. For example, even though men have studied languages for centuries, we understand very little about language. In contrast, everyone uses television sets and telephones, and a few people do understand them deeply.

Science and technology inject into our environment an increasing part that is inherently understandable and controllable. To this we adapt, behaviorally, linguistically, and in attitude, in the old mysterious way in which man has always managed to live. In so doing we acquire new needs and new standards. A society that functioned well in the absence of telephones, automobiles, and electric power is replaced by a society that would collapse without them.

Communication is a particularly apt field in which to discuss and illustrate the impact, actual and potential, of the understanding of science and power of technology on society. Electrical communication has changed our lives profoundly within the span of our memories. Further, electrical communication clearly exemplifies the applicability and power of science. And it illustrates as no other field can the range from the comparatively simple, exemplified by the local broadcasting station and the

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This article has been adapted from the talk given by John R. Pierce at Caltech's 75th Anniversary Conference on October 25. Dr. Pierce is research director of the Bell Telephone Laboratories. A Caltech graduate ('33, MS '34, PhD '36), he was one of 23 alumni who were presented with distinguished service awards at the 75th Anniversary.

home receiver, to the incredibly complicated and interdependent, exemplified in common-carrier communication systems.

This division between the technologically simple and the technologically complex reflects a difference in the purpose and function of mass communication, such as television, and the purpose and function of personal communication, such as telephony. Mass communication is necessarily aimed at majorities or large minorities. It is one-way; it is aimed from the few to the many. It is a unifying and conservative element in our society. As such, its effects have been tremendous.

We are rapidly approaching a society without "sticks" or "boondocks," except those which are growing in the central slums of metropolitan areas. Television brings, into the remotest home, launchings from Cape Kennedy, sports from all parts of the continent, even (via satellite) live events from across the ocean, and a nationally uniform brand of music, comedy, and soap opera.

In the face of television it is difficult for differences of dialect, of interest, or of attitude to persist. This makes television the greatest unifying force ever to act upon man. A voice and a picture on television may not yet be able to tell us what to think about a matter, but they very effectively decide what we will be thinking about, and that may be as remote physically as the war in Vietnam.

The impact of the telephone and other common-carrier communications is quite different from that of mass communication. The telephone is inherently the tool of the individual, not of the majority, or the society. It is the means by which we conduct the business of life—ordering groceries, calling the doctor, making appointments and reservations.

Unlike mass communications, which could have a profound impact on even a primitive society, the telephone is inherently a part of a way of life which has been shaped by automobiles, airplanes, electric power, standardized uniform merchandise, and a pattern of credit—and especially by the telephone itself. We use the telephone because we have come to have interests that lie beyond the home, the family, and the neighborhood. It seems to me that, except for some government and business usage, a telephone system would have little immediate impact or value in a primitive society.

But how did these revolutionary powers of communication come into being? Their source is discovery and invention. Discovery and invention may or may not meet the needs of society; in fact, needs are as often created as satisfied by them.

I am sure that, when Alexander Graham Bell invented the telephone, what common-carrier communication felt it *really* needed was better multiplex telegraphy, and perhaps practical automatic telegraphy. In fact, Bell was working on a new kind of multiplex telegraph—the harmonic telegraph—when he invented the telephone. What the world got through this invention was a revolutionary system of communication which has swamped the telegram, and indeed the letter, as a means of interpersonal communication.

De Forest was seeking a detector for wireless telegraphy when he invented the vacuum tube. The invention led to worldwide telephony and to radio broadcasting. Television languished as an interesting idea for years until science and technology gave us an advanced electronic art and Zworykin invented the iconoscope. Babbage tried to make a well-thought-out and sophisticated computer in the nineteenth century and failed. The computer was reinvented and easily realized, using the art supplied by telephone switching, by Aiken and Stibitz around 1940. The vacuum tube made it possible for Eckert and Mauchly to make a fast electronic calculator. Von Neumann provided the stored program. And the transistor made the computer economical, reliable, and profitable.

If discovery and invention have been so vital in the revolutionary effect which communication has already had on our lives, what may they do to and for us in the future? What, for instance, may we expect from advances in mass communication? For one thing, we expect its effective extension into lands with less advanced communication technology. Already, the transistor radio has provided a direct link between otherwise isolated people and their central governments. Even the Bedouin on his camel can hear that he is part of a nation and learn of its problems and aspirations.

A television receiver is expensive and complicated compared with a transistor radio, but I believe that communication satellites may make television available in undeveloped countries. It is at present impractical to broadcast from a satellite directly to a standard television receiver; the power required is too large, and such broadcasting may remain impractical for a considerable period. It is practical, however, to launch a satellite which will send out a signal with a few hundred watts power; in fact, the Soviet Union has done this. A ground station costing only a few thousand dollars could receive television signals from such a satellite. The received signals could be carried for short distances by cable or could be distributed in local areas by means of cheap, low-power transmitters.

Thus, by means of an entirely feasible communication satellite, television could be transmitted from the capital of a nation to many towns and villages, where it could be viewed in schools or other public buildings. The cost of such a satellite television distribution system would be considerable, but so are other vital government expenses—those for defense and education, for example. The impact could be tremendous.

Consider Nigeria as an example, a nation of over 50 million people which has established English as the language of its schools. Nationwide television could be of tremendous value there as a motivation for learning English, as a means for establishing and maintaining a standard English, and as a means for making nationhood meaningful and desirable to the population. I believe that television of this sort would be almost equally valuable in far more advanced nations, such as India and China.

Space technology has advanced to a point where satellites may be very economical for domestic communication. But we already have adequate domestic network facilities, and satellites could not make television different for us, but only cheaper to distribute. Indeed, the popular revolution in television distribution now under way is in quite the opposite direction; that is, wired distribution provided by CATV (community antenna television) services, instead of distribution by radio.

CATV was initially established to provide television to remote or shadowed areas where the direct signal is inadequate. Signals from a hilltop antenna were amplified and distributed by cables, which themselves have amplifiers at regular intervals. It was found that subscribers were anxious to pay a few dollars a month for an adequate TV signal, even in cities where a fair, but inferior, signal can be obtained from a rooftop antenna.

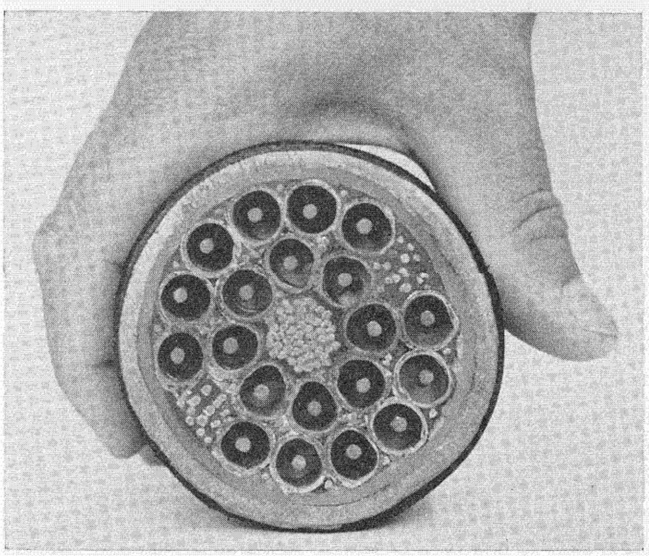
But CATV has another potentiality as well. Through importation of signals from a distance, it can provide any community with as many channels as are available to the residents of Los Angeles or New York. Here indeed is the ultimate in the abolition of the "sticks" and "boondocks."

CATV seems to be a tremendous advance, a real wave of the future compared with anything else on the television horizon. If it survives, it may help to bring about another long-time dream, the delivery of newspapers to homes by wire, though at least two problems must be overcome if this is to succeed. The smaller of these problems is economical broadband transmission. An extra channel on a CATV network could provide this. The other problem is that of the bulk of a newspaper. People *want* big papers, and especially papers with lots of advertisements. But they wouldn't want to have these spew out, unfolded, onto the living room floor, and they wouldn't want to have rolls of newsprint delivered and stored away in their homes. However, a microfilm newspaper might be acceptable. Its success would depend on an economical, convenient, high resolution viewing device and on some practical way of recording images with microfilm resolution. Conventional photography, and even the Land Camera process, seem inadequate. Perhaps science will provide an answer.

If it does, the impact could be tremendous. Experience shows that people want local news and local advertisements in newspapers, as well as national news and national advertisements. In a newspaper distributed by wire, it would seem practical to tailor some news and advertisements to neighborhoods if that proved profitable. Indeed, to some degree, mass communications might be nearly individualized in this process. Television could remain the truly national unifying force that it is.

In the case of individual communication, exemplified by the use of the telephone in our business and private lives, the revolution I foresee will be based on various specific advances which will make cheaper both transmission and the station equipment at the ends of transmission circuits. The cost of transmission goes down as we send more signals over a given path. We can send more signals by providing transmission paths of greater bandwidth.

Today we have advanced far beyond the era in which one pair of wires carried one voice signal. A digital transmission system called T1 can send 24 two-way telephone channels or 1.5 million data bits per second over two pairs of wires in cables. The L4 system sends 3,600 telephone conversations one way over a single "pipe" in a coaxial



This 20-tube coaxial cable handles more than 30,000 voice channels simultaneously.

cable, and there are 20 such pipes in the cable. A microwave transmission route can accommodate as many as 12,000 telephone channels.

What have science and technology provided which will enable us to send large bundles of channels economically? There are several things in immediate prospect, the simplest of which is a potential revolution in microwave systems. The extension of the operation of solid state devices into the microwave range has made it possible to build microwave repeaters of extremely high reliability and extremely low power consumption. Thus, it is possible to build small, cheap, trouble-free repeaters and to power them economically. Perhaps this will lead to use of microwave repeaters spaced frequently along roads rather than on remote hilltops.

The same advances in electronics, together with boosters of the power of the Titan III, have made it immediately practical to launch communication satellites which could supply as many as 100,000 telephone circuits between, say, 5 to 10 principal cities in the United States. Such a satellite system could be established in a few years, and it could in this short time substantially increase the number of long distance circuits available in this country. Further, in concert with terrestrial facilities, the satellite could incorporate switching equipment which would transfer blocks of circuits from one pair of cities to another in meeting fluctuations of demand.

Further in the future, we can see that it will become technologically possible to provide circuits of almost unlimited bandwidth by means of the coherent light generated by lasers. We have suitable lasers. We have, in lenses consisting of gas flowing through alternately hot and cold regions, a means for guiding light through buried pipes. We have modulators for impressing signals on the light and detectors for translating the received light signals into electric current, but we are not yet able to build a useful laser communication system.

We could have new types of microwave systems, satellite systems with a capacity of over 100,000 telephone circuits, and millimeter waveguide systems at any time by deciding to go ahead and by spending the money. In the case of optical transmission, we need more research and experience.

Integrated circuits, or microelectronics, will make it possible to produce a complicated circuit almost as cheaply as a transistor. The circuit configuration is impressed, hundreds at a time, on the surface of a wafer of silicon, and aside from this, the steps in production are essentially those required in making single devices.

This means that it will be possible at a low cost to put very complicated yet highly reliable electronic equipment—as complicated as a very small digital computer—almost anywhere; in your telephone set, in your car, or even in your pocket. What this may do in providing all sorts of new services staggers, indeed paralyzes, my imagination. What we will do with these tools I don't fully know. But I feel that we can describe the impact in general terms.

Initially, in primitive electrical communication, we dealt with two apparently distinct inventions. One of these was the telegraph, which communicated by on-off signals that produced audible clicks. The other early invention was the telephone of Alexander Graham Bell, which transmitted, over a limited distance and faintly, the sound of the human voice.

If we look at the nervous system of man, we find no such distinction. The nerve impulses that travel from our fingers to our brain in using the sense of touch, from the eyes to the brain in enabling us to see, and from the ear to the brain enabling us to hear are all the same distinct, spikelike electric signals. They do not differ at all in quality. There is a uniform medium through which all our senses serve us. The same spikelike pulses are used to control the hands that we use in writing and to control the muscles that we use in speaking.

As the arts of telephony and telegraphy advanced, the distinction between them became vague. Telegraph signals were multiplexed, or transmitted many at a time, over telephone lines in much the way that Alexander Graham Bell had envisioned in his work on the harmonic telegraph. Finally, it became clear that telephone signals could be transmitted by off-on impulses, by a method which we call PCM or pulse code modulation. PCM is now coming into increasing use in the telephone system. It was not, however, until 1948 that Claude Shannon gave in his mathematical theory of communication a broad, coherent, and useful theory of the process of communication which includes the telephone, the telegraph, and all other means of communication.

Through advances in technology and through the understanding provided by Shannon's work, we are now achieving in electrical communication, both conceptually and practically, something approaching the universality that has been built into the communicating senses of man since before the time he learned to talk and write.

We can expect that in the future there will be many new signals and many new uses of communication. Whatever these may be, we can be sure of two things: modern electrical communication networks will be adaptable to the transmission of all of them, and Shannon's general theory will be a common measure and tool for studying and relating all these forms of communication.

What will these new forms of communication be? I have already mentioned the possibility of greatly improved mobile telephony, such as a phone in every car and even telephones in the pocket. But future communications will embrace much more than voice. The Bell System is engaged in a determined effort to introduce person-to-person television on a large scale. Facsimile may have an increasing use for business and library purposes. Even telewriting may find its place in connection with conferences and lectures convened through electrical communication rather than physical travel.

In conferences, as in a two-party communication, we will want to make data available and to send letters and reports by means of data transmission. I believe that within a few years virtually all business records and correspondence will be put into machine-readable form when first typed. If this is done, it will be possible to send text from office to office as easily as making a telephone call.

Further, computers can index and search machine-readable material. Computers can be used in editing and correcting text without complete retyping; they can even be used to a degree in proofreading. From a corrected machine-readable copy, computers can automatically produce printed material, correctly paginated and with justified lines. They can also construct charts, graphs, and line drawings and insert them at specified points in the text. Thus, computers will take care of a great deal of office drudgery.

By means of electrical communication, offices will be linked to other offices, to files, to reproduction facilities, and to other resources. This linkage will extend through other business activities as well. The TOUCH-TONER telephone set generates signals that (unlike dial pulses) can travel over any voice circuit, even to the farthest corners of the world. Thus, the system can be used to query computers or to control machinery wherever the telephone can reach. This is already in limited use in banking and merchandising.

If one can query a computer from any telephone, how can the computer reply? It can reply in spoken words. At present, such words are recorded words, but voice recording is an inefficient means of information storage alien to the digital computer. There are fair prospects that computers will eventually be able to read aloud intelligibly from phonetically spelled data stored in their memories and even transcribe between ordinary text and phonetically spelled text.

In the future we may be able to query any number of information sources from a distance about weather, hotels, stores, sports, theatres, or other matters and receive voice replies tailored to our specific queries. We may even make such queries via a keyboard in simple English. As the computer will be able to respond to simple, unambiguous queries only, it will sometimes fail to undertsand or misunderstand. If it replies amiss, or says that it didn't understand the query, we will be able to try again, perhaps in words suggested by the computer. We can use our own intelligence to overcome the stupidity of computers and the accuracy and speed of the computer to supplement our slow and fallible mental processes.

In the future, science and technology, following the trend toward generalization, will increase the capacity of our common-carrier communication network to provide all sorts of communication over the same channels. Microelectronics and other advances will provide terminal equipment or transducers which will link this network to all our senses and to a growing variety of uses. What this will do to our life I can only guess.

The certainty is that science provides an understanding which is alien to everyday life. We understand a little in this way, but that little is extremely powerful. Through research and development, this understanding has so altered our environment that we live lives which are essentially different from those of earlier generations. The man who lives successfully in the world of the future need not understand that world in the scientific sense, but it is the understanding of science which is bringing that world into being.

One form of communication in the future will be by person-to-person television.