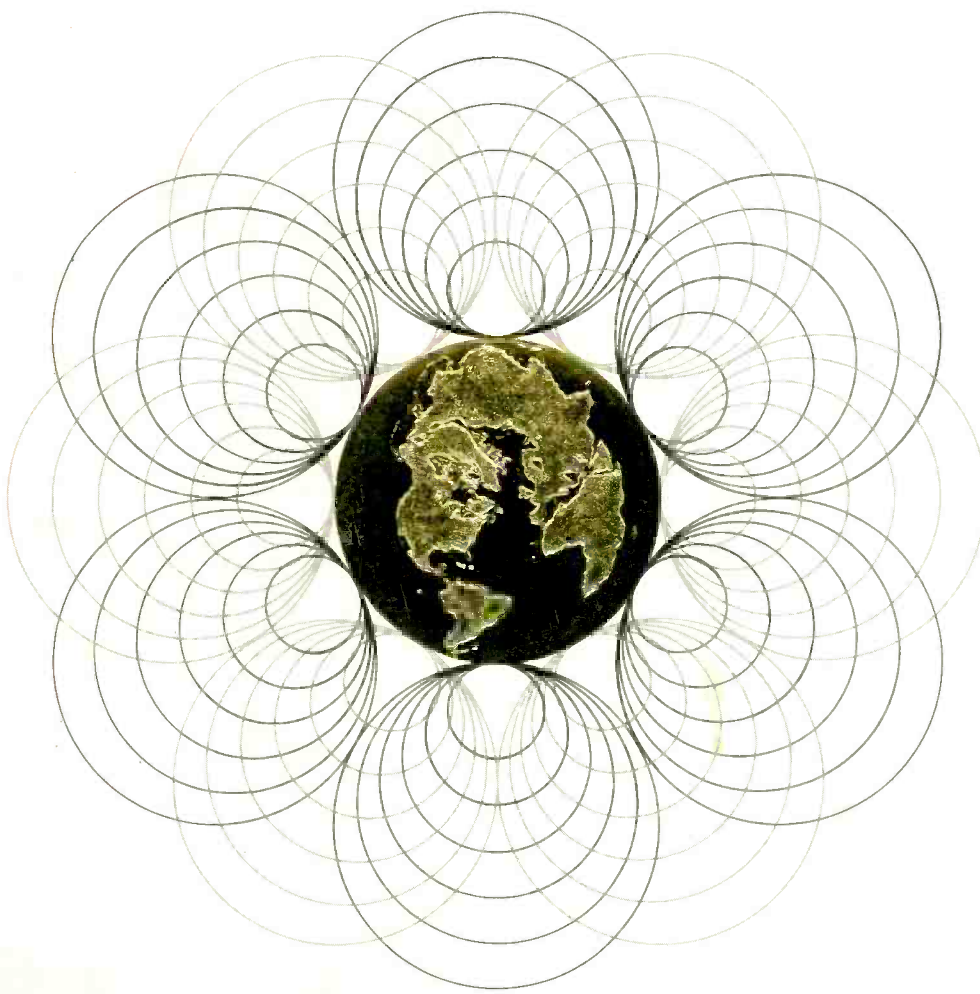
RCA Engineer

Vol 23 | No 3
Oct | Nov
1977



advanced communications for the nineteen-eighties

RCA Engineer

A technical journal published by
RCA Research and Engineering
Bldg. 204-2
Cherry Hill, N.J. 08101
Tel. PY-4254 (609-779-4254)
Indexed annually in the Apr/May issue.

Our cover is an interpretation of worldwide communications by Bob Canary, who is a graphic designer at ATL in Camden, N.J.

- •To disseminate to RCA engineers technical information of professional value
- •To publish in an appropriate manner important technical developments at RCA, and the role of the engineer
- •To serve as a medium of interchange of technical information between various groups at RCA
- •To create a community of engineering interest within the company by stressing the interrelated nature of all technical contributions
- •To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field
- •To provide a convenient means by which the RCA engineer may review his professional work before associates and engineering management
- •To announce outstanding and unusual achievements of RCA engineers in a manner most likely to enhance their prestige and professional status.

RCA's communications environment—

economics is as big a challenge as climate and terrain

This is the 20th anniversary of Sputnik—a perceived threat that galvanized us into a national technical effort unmatched in peacetime.

One unforeseen benefit of that effort was satellite-aided communications—a technological, social, political, and economic development of global importance. For RCA, this has changed the communications business substantially. We now have three important communications companies—Alascom, Americom, and Globcom—all of which have benefited significantly from the space effort.

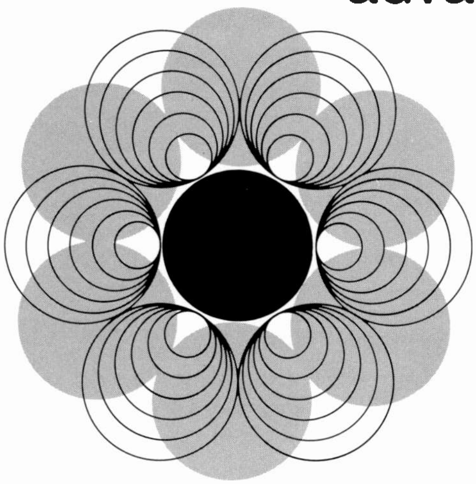
Although my own association with these companies dates back only several months, two initial impressions remain with me from almost my first day. First, RCA engineers have designed and developed technically unsurpassed communications systems and often have operated these facilities in forbidding climates and on rigorous terrains. Second, RCA management has authorized enormous capital expenditures to develop the state-of-the-art equipment and facilities for these three communications companies.

RCA scientists and engineers can be justly proud of their accomplishments, but a tremendous engineering frontier is still open. Satellite and associated ground technology are new and glamorous; yet the more prosaic cable and switching engineering field probably has the potential for just as high "payback." And, as I look ahead, "payback" will be the primary criterion in determining future design and development engineering priorities in the communications business.

But the RCA engineering community is no stranger to an environment where cost-effective performance is the prime requisite. And you can be sure that I will join with you in carrying forward such engineering programs. It is vital to our continued joint success.

Julius Koppelman
Group Vice President
RCA Corporation
Cherry Hill, N.J.

advanced communications for the 1980s



Three trends are increasing the efficiency and capacity of the communications industry. All three ideas—digital communication, automation, and communication satellites—have been with us for some time, but their increased use is now affecting the industry and RCA strongly.

satellite communications

Satellites now have more communication capacity than all the transoceanic cables now installed.

4, 12, 40, 52

digital communication

Digital equipment costs less, noise is not cumulative, encryption is easier, and digital systems can handle many types of transmission (voice, data, music) simultaneously.

4, 36, 40

automated operations and management

Over 80% of RCA Globcom's overseas telex calls now move through a computerized system; automated circuit management will soon maintain the entire Globcom system.

19, 61

keeping technically current

Remember that survey? How do RCA's engineers obtain new technical information and stay up to date? Where do you stand?

18, 30

Coming up

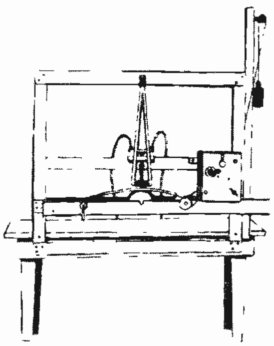
Our next issue (Dec/Jan) covers the **broadcast** end of **advanced communications**, including **digital tv, circular polarization,** and **electronic journalism.**

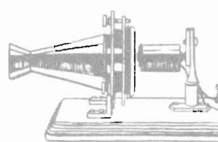
Later issues will have **radar, software,** and **space technology** themes.

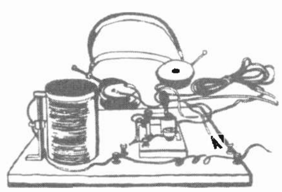
RCA Engineer

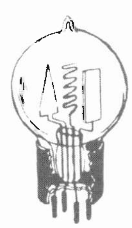
Vol. 23|No. 3 Oct|Nov 1977

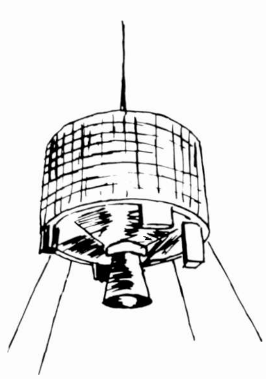
Communication technology: an overview











The geostationary satellite provided the same kind of quantum jump in communications capacity that Marconi's wireless did. Despite the added capacity with satellite systems, new bottlenecks have developed.

K. H. Powers

Since the inauguration of electrical communication by Samuel F.B. Morse in the 1840s, telecommunication has experienced steady dynamic growth and its history has been characterized by a continual race between the requirements for communication capacity and new technological developments. Since Morse's telegraph, the most significant milestones in the development of communication have been: Bell's invention of the telephone in 1985; Marconi's exploitation of wireless telegraphy in 1900; DeForest's invention of the electronic amplifier in 1908; Shockley's invention of the transistor in 1948; and the launching of the first geostationary satellite in 1964. Each of these milestones has increased the capacity for world communications. Of all of these milestones, however, I would select two—Marconi's wireless and the geostationary satellite—as representing real quantum jumps in the potential communication capacity.

Marconi's development freed the world from cable-connected installations, and at the same time, opened up the spectrum available for long-distance communications to about 30 MHz. By the same token, the satellite has freed us from line-of-sight limitations in the vast spectrum above 30 MHz.

Keeping up with the growth rate

The growth of worldwide telecommunications over the past hundred years has been dynamic, yet very stable (Fig. 1). For the past 50 years or more, the telephone industry has been able to predict quite precisely (for five to ten years out) the total system capacity that would be required to service its telephone customers. To meet the high rate of growth without utter chaos, telephone engineers have been continuously developing new switching techniques and new transmission systems to use the existing telephone plant more effectively.

On an international basis, the early growth in overseas communications was provided first by submarine cables and later by high-frequency radio. This met the needs from

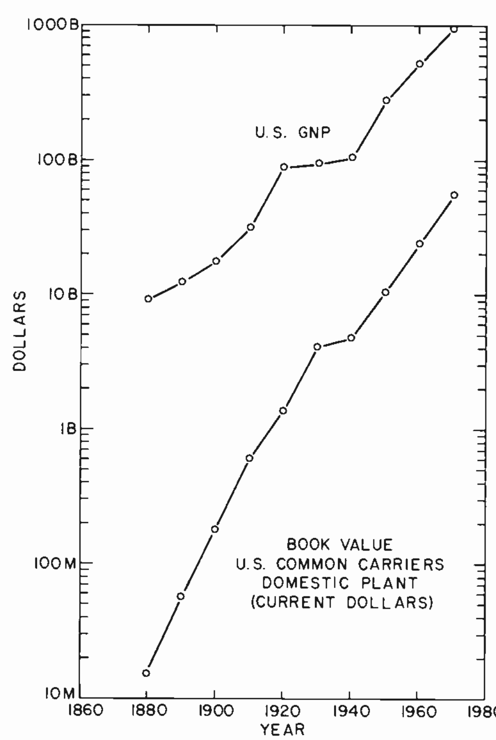


Fig. 1
Investment in communications has grown at a compound rate of 9.5% over the past century, as compared with only 5.3% for the GNP.

Reprint RE-23-3-2
Final manuscript received October 13, 1977.

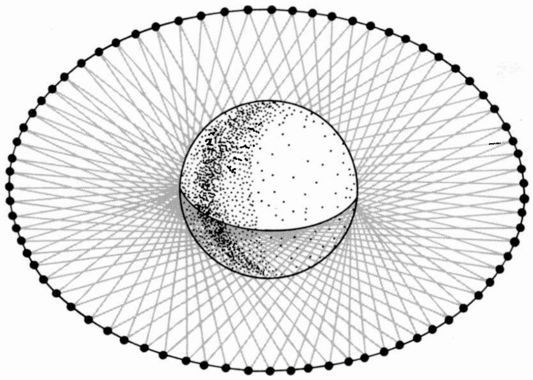
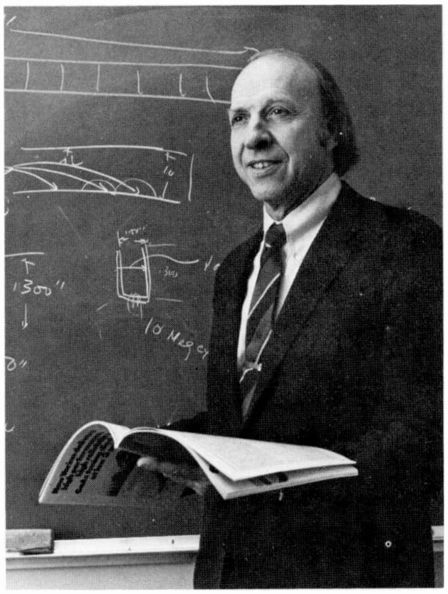


Fig. 2
There are only a finite number of slots available for geostationary communications satellites operating at the same frequency. Earth-station antenna beamwidth is the limiting factor. Presently, however, there is still unused space capacity, but a connection bottleneck on the ground.



Kerns Powers has been Staff Vice President for Communications Research at RCA Laboratories since June 1977. He had previously been Director of the Communications Research Laboratory there since 1966. He has served on several government committees concerned with satellite and terrestrial communications, and also holds six patents.

Contact him at:
RCA Laboratories
Princeton, N.J.
Ext. 2746

the early 1900s up to about the second World War, at which time the high-frequency radio spectrum became too congested. New submarine cables using extensive multiplexing were then accelerated into service and have essentially taken care of the increasing demand for capacity until recent years. Much development has gone into increasing the cables' bandwidth, which is relatively narrow. Although submarine cables are still being installed every year, most of the growth in international communications is taking place via satellites.

Since the launch of Sputnik in 1957 and the development of the geostationary satellite Syncom in the early 1960s, the Intelsat series of satellites has produced since 1965 four generations of geostationary satellites, placed in orbit over the Atlantic, Pacific, and Indian Oceans. More than twenty satellites have been launched in the Intelsat series and the system now serves a ground configuration of over 120 earth stations throughout the world. In addition, domestic communication satellites have been launched by the Soviet Union, Canada, a European consortium (ESRO), and the United States. The total capacity of communication satellites in orbit today now exceeds that of all the transoceanic cables that have been installed.

The backhaul bottleneck

With all this new capacity in orbit, one would think that technology had finally caught up with demand and that future growth can be accommodated by simply launching new satellites and shifting to new higher-frequency bands. The number of geostationsary satellites that can share a given frequency band is limited, however, by the beamwidth of the earth-station antennas (Fig. 2). The domestic systems currently in operation are assigned orbital slots at a nominal 4° separation. Although empty orbital slots and unused frequency bands are currently available, the bottleneck in capacity has unfortunately just shifted back to the ground. Because satellite and terrestrial services share the 4/6-GHz bands, the gateway earth stations of the major population centers are customarily sited in quiet, shielded locations several miles from their major customers in the city centers. These earth stations are then connected to the downtown central office by microwave backhaul, where line-of-sight limitations and frequency congestion are again encountered. Indeed, many of the gateway backhauls have already reached their limits in frequency availability and the existing installations cannot use all of the space-segment capacity available.

Even if optical links or some other magical solution to the backhaul problem were suddenly found, a bottleneck would still exist in the local loops that connect the subscribers with the central office. Fiber optics promises relief in this situation, but much development remains to be done. The most promising near-term solution is in using satellites operating at 12/14 GHz, where the exclusive frequency allocation and the shorter wavelengths will permit the use of small earth stations located on customer premises, thus eliminating both the backhaul and the local loops.

Technology trends in satellite communications

The earliest Intelsat earth-station antennas had large dishes up to a hundred feet in diameter and employed cryogenically-cooled masers and parametric amplifiers with noise temperatures of 15-20°K to detect the weak signals from the early low-powered satellites. (The Intelsat 5-watt transponder with earth-coverage beam provided an EIRP* of 22 dBW.)

The domestic satellite systems have been tailored after a more-recent higher-power generation of satellites (regional beams, EIRP = 32 dBW) and use a somewhat smaller earth-station antenna, typically 10 to 13 meters in diameter. The trend has also been toward lower-cost thermoelectrically-cooled parametric amplifiers at noise temperatures of 40 to 100° K.

Although the cost-effectiveness of satellite transmission has been shown to be better than that for a terrestrial microwave circuit at distances greater than about 1000 miles, one of the most significant attributes of the geostationary satellite is its ability to communicate simultaneously to multiple points on the earth's surface. We have therefore seen an increased use of satellites in the broadcasting service, particularly television. This application has been accompanied by a trend toward even smaller receive-only earth stations, with 4½- to 6-meter earth-station antennas for cable television operators becoming typical. Fig. 3 shows a typical small receive-only earth

*EIRP stands for effective isotropic radiated power, which is the rf power multiplied by the antenna gain.

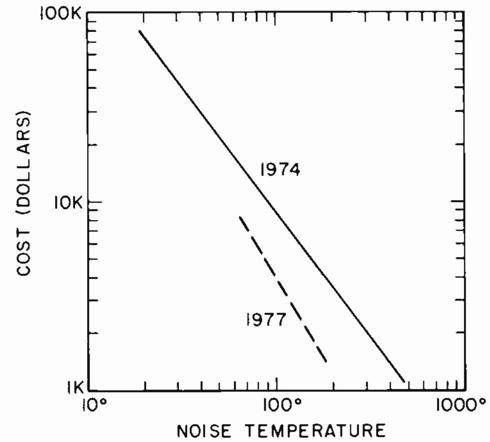


Fig. 4
Low-noise amplifiers for earth stations are decreasing in cost. The trend is for less sensitivity at the receiver at lower cost, but more power at the satellite.

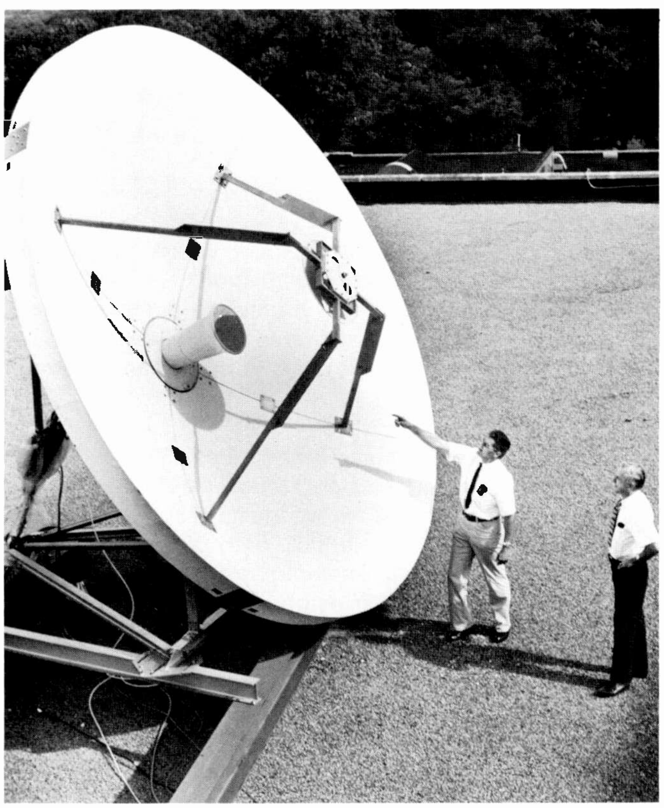


Fig. 3
Smaller earth stations are replacing the earlier 30-m- and 10-m-diameter dishes. This 5-m-dia receive-only station, located on the roof of an RCA Laboratories building in Princeton, N.J., is used for experiments with RCA Satcom satellites. The RCA engineers in the photo are Lewis Stetz (left) and Joseph Zenel.

station. The low-noise amplifiers are also giving way to even lower-cost FET transistor amplifiers with equivalent noise temperatures down to 120° K. Fig. 4 shows the cost trend-line of low-noise amplifiers.

As the next generation of shuttle-launched satellites at 12/14 GHz comes into service, we will see a continuation of the trend toward more EIRP in space and a larger number of smaller earth stations in the ground segment.

EIRP might be increased by either increasing the satellite's output power or by employing spot beams with on-board beam switching. Both these solutions involve tradeoffs. An increase in power output will increase the payload weight and, thus, will limit the number of transponder channels. The Canadian/U.S. Communication Technology Satellite, for example, carries a 200-W TWTA, but has only one such transponder; the RCA Satcom, on the other hand, uses 5-W TWTAs, but has 24 such transponders.

Beam-switching satellites would concentrate the output power into regional beams that are switched to the different earth stations in accordance with the traffic. This mode of operation is more suited to point-to-point communications than to the nationwide coverage that is now common with satellite systems.

Presently, communications satellites consist of a relatively unsophisticated communications package inside a highly sophisticated bus. This situation is changing, however, and the communication systems in future satellites will be capable of doing much more than simply rebroadcasting what they receive.

In general terms, anything the satellite can do to sort and identify message segments will make the ground equipment less complex and less costly. It might be cheaper to put the signal-processing equipment in one location—the satellite—than in all the ground locations. Since time division multiple access (TDMA) is now a reality for space communication (to be incorporated in the SBS and TDRSS satellites in 1979), there will probably be a trend away from the "microwave repeater" satellite of today toward more on-board signal processing, with packet-switching protocols done in the satellite.

Developments in multiplexing

As technologists work to develop new media and devices for increasing communication capacity, communication engineers are working equally hard to develop new techniques to make maximum use of the capacity available. One technique is multiplexing, in which several channels of communication are combined into a single signal for transmission over a single circuit. This has been a necessary development to provide the engineers with the flexibility to match the communication signals to be transmitted with the bandwidth of the circuits available. In a sense, time-division multiplex preceded frequency-division multiplex as messages were transmitted over telegraph wires in a time-division manner, except that the time-division blocks consisted of complete messages. Frequency-division multiplexing was first developed for carrier systems in the telephone industry and has seen extensive use in microwave systems. The more modern version of time-division multiplex, which interleaves samples of several messages simultaneously, had to await refined digital techniques and is a more recent development. A third type of multiplex, sometimes referred to as code-division multiplex, is a new concept that uses complex wideband orthogonal signals to simultaneously multiplex many channels in the same frequency band while overlapping in time. Code-division multiplex has not seen extensive development as yet.

Bandwidth compression techniques

Another major area of communication techniques development has been bandwidth compression, which is aimed at using the spectrum more efficiently. Single-sideband modulation was one of the earliest of these techniques, whereby voice channels could be multiplexed in a carrier system in approximately one-half the bandwidth that would be required if double-sideband amplitude modulation were used. The use of vestigial sideband in television transmission is another example of a move in this direction. More impressive, however, is the NTSC color tv system, which uses a time-interlaced, frequency-interleaved subcarrier to multiplex the chrominance information in the same bandwidth as the luminance.

The more sophisticated bandwidth compression ideas, born out of Shannon's information theory, wherein the inherent statistical redundancy in the signals is used to reduce the required bandwidth for transmission, have had a slow history of development because of the complexity of terminal equipment that would be required to use these techniques effectively. Bandwidth compression of speech signals has achieved large factors in the development of vocoders with terminal equipment so complex that their application has been limited to the military, where the additional requirement of encryption has justified the high cost. However, in the past ten years, the technologists have come to the rescue again with the development of large-scale integrated circuits for which the large storage and the very complex signal-processing algorithms can be implemented without undue cost and size. Recently the requirement for privacy in mobile radios has led to the introduction of an integrated continuously variable slope delta (CVSD) modulation chip and a companion key generator chip in commercial mobile service. This technology, with perhaps a linear predictive coding technique, should quickly find its way into microwave and satellite voice circuits.

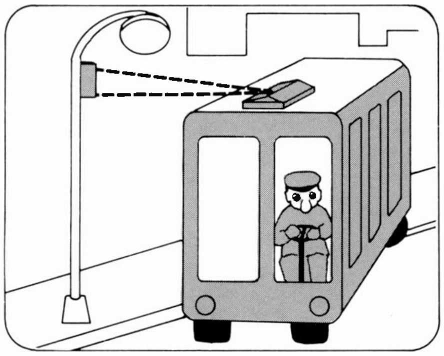
Bandwidth reduction of television has been the subject of research for over 20 years, yet only recently has it been achieved in commercially available equipment. Here extensive new digital technology at high logic speeds is required, but the cost of this terminal equipment is still too high to permit extensive use, and in most applications the terminal costs exceed the cost of the bandwidth they save. Thus digital television must still await the large-volume application that will justify the development of a high-speed integrated A-to-D converter, a low-cost digital frame store, and a high-speed data-compression processor.

Conclusion

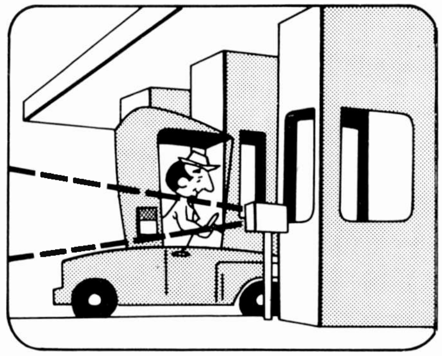
Many trends are clearly evident. Communication satellites are still in their infancy and their communication payloads are currently little more sophisticated than a microwave repeater. In future system generations we can expect to see more power and complexity in orbit and further proliferation of smaller lower-cost earth stations. The space shuttle, which will be operational by 1980, will reduce launching costs and permit heavier payloads. Extensive use of beam switching will permit higher EIRP for the same payload weight. On-board signal processing and storage will permit message switching in orbit, further simplifying the earth terminals. Indeed, packet-switching protocols and TDMA are just around the corner.

New communication technologies and devices will continue to reduce costs and permit higher degrees of complexity. LSI and microprocessors are here, CCDs and SAW devices not far behind. Solid-state microwave devices will ultimately replace TWTs and will continue to provide lower-cost low-noise amplifiers. There is still a clear trend toward digital transmission for voice and video as well as data, although this trend has lagged behind predictions for thirty years. Fiber optics seems to have leap-frogged millimeter waveguides and will no doubt find application in undersea cables as well as in terrestrial trunks and local loops.

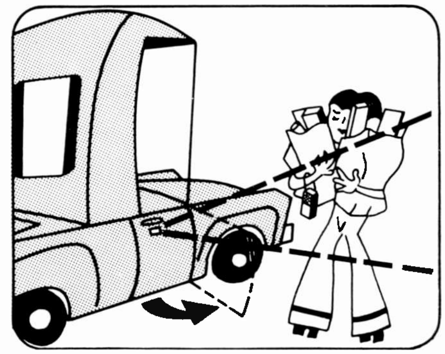
The race between technology and demand in telecommunication has been evident for over a century, with each leading the other at the same time in different segments of the business. We have a tortoise-and-hare phenomenon, with economics serving the role as the pacemaker. As demand exceeds the technology supply, a communication bottleneck develops, whereas in the opposite case, a lack of investment capital prevents excessive surplus capacity. Undoubtedly, the dynamic growth pattern we have seen will continue. One big question remains: what will be the next major milestone?



automatic vehicle location



automatic toll collection



radio lock

Whither telecommunications?

H. Staras

Telecommunications is growing by expanding its traditional markets and branching out into new ones. How many of this article's predictions will be realities twenty years from now?

The recent explosion in CB radio marks still another milestone in the dramatic growth in radio communications since the early days of a.m. transmission. Even if this particular phenomenon turns out to be only a fad rather than the beginning of a major new radio communication business, one thing is sure—radio communications continues to grow rapidly, and solid-state technology continues to grow with it to make equipment more reliable, less expensive, and capable of operating at ever-higher frequencies. This last requirement is a must if radio communication is to continue to grow, since the lower frequency bands are very crowded, and conflict between different user groups is already evident.

With that as a background, the following is an attempt to identify some new radio communication systems that may become a reality during the remaining years of this century

Citizen's Band

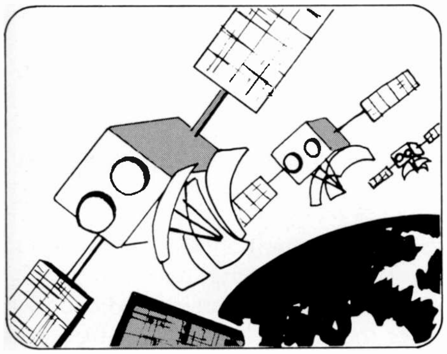
Call for help on your pocket-sized "urban distress" CB.

CB radio "took off" during the oil crisis of 1973. The conventional explanation relates to the truckers' attempt to circumvent the newly-imposed 55-mi/h speed limit by notifying each other where and when the police were. By now, there is evidence that that feature is much less prominent than it once was, and that CB is frequently used for such desirable ends as notifying the police or health authorities about highway accidents or criminal activity, although just socializing seems to be its most common use. Some hotel/motel chains reportedly are considering implementing CB at their different locations to accept reservations from motorists and to relay information about highway accidents and criminal activity to the appropriate authorities. Extrapolating this trend, portable and even pocket-sized, short-range CB radios may be used at higher frequencies in urban environments to call for help in case of fire, heart attack, or mugging, for example. In this connection, there is some evidence that radio waves at 900 MHz and higher tend to propagate down city streets as in a slightly lossy waveguide. If further data pin down the propagation characteristics more quantitatively and identify the preferred frequencies, then a small array of electronic signposts emplaced in city streets may be used to locate the source of the call for help.

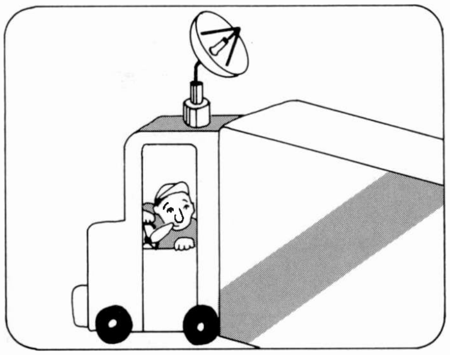
Automatic vehicle location

Electronic signposts may be used to track vehicles.

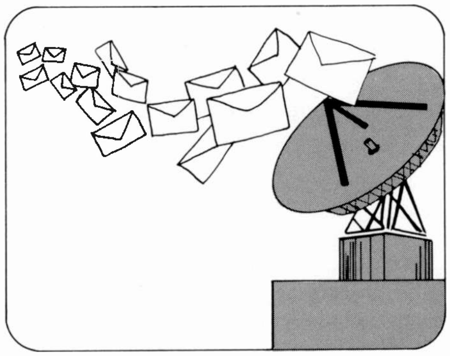
The efficiency of operation of a fleet of land vehicles probably could be increased if management could automatically and continuously monitor the disposition of the vehicles throughout the service area. This holds for buses, police cars, taxis, and commercial delivery vehicles. Several organizations have done a modest amount of work toward developing an automatic vehicle location and tracking system. For fixed-route systems (e.g., buses), it's almost certain that the most effective way of implementing such a system would be with the aid of a limited number of electronic signposts deployed along the bus routes coupled with interpolation between signposts from the odometer readings of the vehicle. The signposts communicate with the vehicle by means of short-range radio signals. The vehicles, upon interrogation, relay to the control center the



expanded satellite communications



earth stations for long-haul trucking



electronic business mail

signpost identification number, the vehicle's own identification number, and the accumulated distance since passing the signpost. This permits the control center to ascertain the location of all vehicles and their adherence to schedule, and then provide specific information to the dispatchers for appropriate action.

For random-route vehicles, the problem is a good deal more complicated. Experimental systems using phase-ranging, pulse-ranging, electronic signposts, and dead-reckoning have been tested. One of the more recent ones involves a dead-reckoning system that uses relatively crude but low-cost odometers and turn sensors in the vehicle. The vehicles transmit digital radio signals carrying elapsed distance and turn angles since the prior communication to a control center, which has the city streets mapped into a computer memory. Even if these estimates are fairly poor, the control center can identify the location of the vehicle quite precisely (within 100 feet or so) because it uses the map of the city to define the permissible motion of the vehicle and so can correct the inaccurate (or missed) information arriving from the vehicle. The U.S. Department of Transportation has recently undertaken a pilot program in Los Angeles to evaluate the performance characteristics of a vehicle-location system that can track randomly moving vehicles. In time, a preferred system among all the competing ones is likely to emerge.

Electronic vehicle identification

The electronic license plate might be the microwave analog to supermarket optical checkout systems.

In these systems, a "label" is attached to the vehicle. An interrogator, which may be imbedded in the roadway, mounted at roadside, or carried in another vehicle, is used to interrogate the "label," which responds with a coded identifying message. Three broad types of these systems have been tested over the years. First are the optical systems, in which the labels have printed bars of different widths and spacings and the interrogator is a light source that scans across the labels. A second system uses a low-frequency loop on the underside of the vehicle and another low-frequency loop buried in the roadway. The loop in the roadway induces a voltage in the vehicle-borne loop, which then retransmits a coded message containing its identification. The third type is the microwave label, which uses a flat, printed-circuit antenna and a coded digital message in the form of shift register with external hard-wired connections that control the code circulating through it. The label does not radiate until it is irradiated by a cw transmission at the designated microwave frequency. When it is so irradiated, the label reflects an amplitude- or phase-modulated microwave signal.

The advantages and disadvantages of these types of labels depend on the system performance characteristics desired. At a supermarket check-out counter, the optical scan system is preferred. But there are interesting possibilities for the others, too. The microwave label, for example, can be the basis for an electronic license plate that can be "read" by an interrogator even while the vehicle is moving at high speed. This can provide a basic element in an automatic toll-collection system on toll roads and bridges, an automatic check-in system for rental vehicles, or even a radio-controlled lock.

The microwave lock system would use no keyhole or other mechanism that could be tampered with from the outside, but would instead emit a weak, very-short-range (feet) cw microwave signal. When the correct "key," in the form of the microwave label described earlier, is dangled in the general area of the radio lock, the radio lock would detect and decode the modulated signal reradiated by the "key" and spring the lock open. Experimental models of such a label, 3" x 6" x ⅛", have been fabricated; even smaller ones are possible in time. Such a radio lock has the intriguing possibility of making door-opening more convenient (no fumbling with keys in the dark or when carrying packages) and more secure (physical access to the lock is not possible from the outside).

This paper was originally presented at the National Telecommunications Conf., Dallas, Tex., in November 1976.
Reprint RE-23-3-11

Satellite communication systems

Both operating frequencies and the number of communication circuits are increasing.

The radio systems described earlier are a bit "iffy," although some of them are almost certain to come to fruition in the next two decades. Satellite communication systems, on the other hand, are already here to stay. They are established and continue to grow rapidly. The largest satellite communication system is Intelsat; a look at its growth projection into the 1990s indicates the expected growth in satellite communications. There are presently about 18,000 telephone circuits in the Intelsat system, but one scenario predicts about 90,000 circuits in 1985 and 300,000 circuits less than 10 years later. When this growth is coupled with the growth in domestic satellite systems in Canada and the United States, and shortly in Brazil, Indonesia, Japan, and possibly Iran, it becomes very clear that a major new communication technique has been born. Present commercial usage is predominantly in the 4/6-GHz band, but Satellite Business Systems, Inc. has announced plans for a commercial system at 12/14 GHz by 1980, and experimental systems are being evaluated in 18/30-GHz band. There is 1 GHz of bandwidth allocated in the 4/6-GHz band, another 1 GHz in the 12/14-GHz band, and 5 GHz of bandwidth in the 18/30-GHz band. Although the United States and Canada have been the leaders in this technology to date, the Europeans and Japanese are beginning to make significant progress. Commercial communications satellites (except in Russia) all use geostationary orbits. Over the Western hemisphere, a proliferation of satellite systems in the past several years has already created a problem with orbital crowding.

By and large, the function of a satellite communication system is to supplement microwave and cable systems transmitting telephone, television, and data signals over long distances. However, there are two situations in which the satellite system becomes the most cost-effective. One occurs when broadcast-mode transmission is required. In this case, the same signal or message is transmitted to many different locations. The improved cost-effectiveness in this situation arises because cable and microwave systems are essentially point-to-point, while a satellite system operates naturally in a broadcast mode.

An obvious example is tv networking. A major reason why tv networking via satellite has not yet been implemented on a significant scale is lack of a "track record" on the part of domestic communication satellite operators, whereas AT&T is a known quantity to the broadcasters. But Home Box Office, a distributor of pay-tv programming to cable operators, and the Public Broadcasting System have made firm commitments to distribute their programs via satellite. In fact, Home Box Office is already operating through RCA Satcom.

The other situation in which a satellite system has an obvious advantage occurs when the population centers that require communication are separated by large distances and hostile intervening terrain makes cable or microwave systems very expensive to install and maintain. Intercontinental traffic is a case in point; hence, the value of the Intelsat system. Alaska, Canada's Northwest Territories, Brazil, Iran, and several other such regions are interested in their own domestic satellite systems for precisely this reason.

In the remainder of this paper, attention will be limited to two specific communication systems that have not gotten as much attention as others. One involves radio communication between over-the road, long-distance truckers and their home bases; the other is the electronic mail system.

Long-distance truck communications

Will small earth stations make satellite communication possible for long-distance trucking?

Police cars, taxis, buses, and delivery vehicles started operating without mobile radio and developed effective operating disciplines without it. However, mobile radio has clearly helped increase their efficiency of operation to the point that it is now probably more common than not for these classes of vehicles to have mobile radio. By the same token, over-the-road trucks and buses presently operate satisfactorily without mobile radio—they have established an operating discipline that permits them to operate without it. However, satellite technology appears capable of providing a cost-effective mode of long-range communication for these vehicles before the end of this century. Satellite communication systems have been designed to provide long-range two-way communication with aircraft (Aerosat) and ships at sea (Marisat and Marots). These tend to be quite expensive. With Aerosat, aircraft must have an antenna that is essentially omni-directional and, therefore, low-gain. This, in turn, requires the satellite to radiate a great deal of power in a narrow bandwidth. The narrow bandwidth, in turn, limits the amount of traffic that can be carried. In effect, this adds up to a high cost per voice or teletype channel. In the case of Marisat, the high cost comes from requiring a stable antenna platform on the ship, even in very high seas.

With land vehicles, these problems are much less serious and the cost can become quite modest if one operational constraint is acceptable; i.e., the land vehicle should stop, pull over to the side of the road, and manually point a 1½- or 2-foot dish, say, toward the satellite. A pilot tone from the satellite could aid this procedure. When the base station is trying to reach the mobile user, a narrowband digital signal could alert the vehicle to stop and receive the call. Assuming this constraint, a long-range telephone or teletype link could be established from the land vehicle to its home base a thousand or more miles away. A rough calculation (operation at L-band/S-band assumed) suggests that a truck or bus would require about $3000 of vehicle radio equipment, and the rental charge for the use of one satellite voice channel would be about $50/month. The main difficulty in bringing such a system into being is not technology, but rather the nature of the business environment. A truck or bus company cannot introduce such a system on its own—a third party must invest the substantial amount of money necessary to place the satellite relay channel in orbit. But there may come a time when a communications satellite operator will see fit to add an L-band/S-band transponder for use by over-the-road vehicles.

Electronic mail system

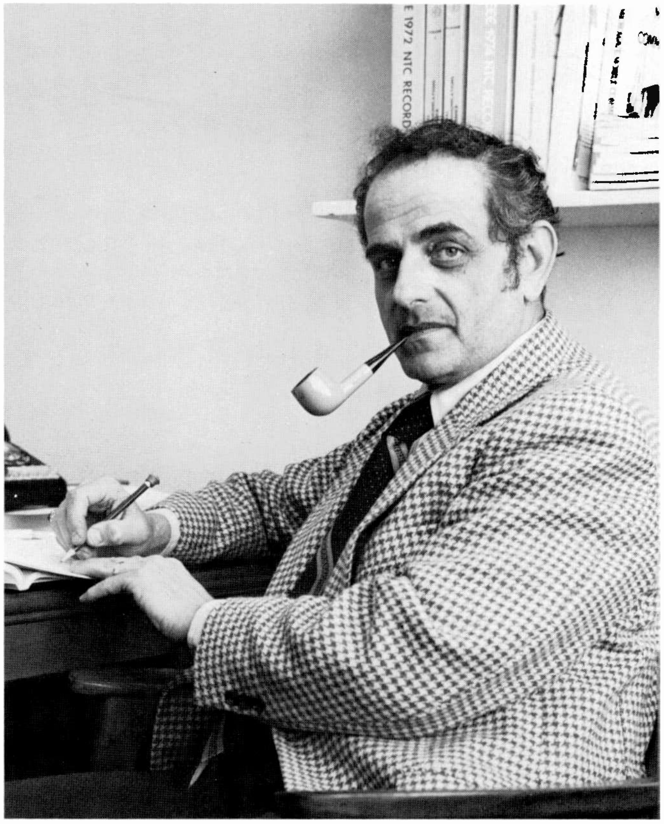
If the Postal Service doesn't implement electronic mail in the next decade or so, then private communication companies will.

There is just too much business mail (more particularly, financial-transaction mail and computer-generated data) not to recognize the value of telecommunications for its distribution. This will become even more pronounced when word-processing machines replace typewriters almost completely. By then, business mail will automatically be in a format eminently suited for transmission by telecommunications. But to put the whole question of the electronic mail system (EMS) into perspective, it should be recognized that communications will probably account for less than 5% of the capital costs of the entire system. Input/output terminals and store-and-forward facilities will account for the lion's share of the costs associated with this new system. Nevertheless, telecommunications, and satellite communications, in particular, will be the vital new highway to replace or, at least, complement trucks, trains, and planes for mail service in the future. This trend will no doubt be accentuated by the ever-increasing cost of, and pressure to conserve, fuel.

Note, though, that correspondence mail, especially of the social type, may not be amenable to handling by EMS for a long time to come. However, business mail, in the form of advertising and form letters that are sent to many different addressees, is particularly cost-effective for EMS and should be sufficient economic justification. But even regular business mail, which is characteristically short and to the point, and which comes with preprinted letterheads or on preprinted forms, is also quite cost-effective. In this connection it should be mentioned that the off-hour transmission of nationwide newspapers and journals for printing and distribution in many different regions of the country also appears to be quite cost-effective and some such systems are being tried out now outside the purview of the U.S. Postal Service. It is perhaps worth special note that business mail, particularly of the financial variety, requires a very low probability of error. Satellite communication links appear to have characteristics that are the closest approximation yet discovered to an ideal white gaussian noise channel, so the likelihood that they will meet the low error rates required for financial transactions appears very good.

Conclusion

This paper has outlined a *potpourri* of communications systems that are likely to see the light of day before this century comes to a close. The reader is requested to remember those predictions made here that do materialize, and to forget those that fail to do so.



Harold Staras has had almost 30 years of professional experience (23 of them with RCA) in research and development, primarily in areas relating to propagation, communication, and radar systems. He is presently involved in satellite communication studies supporting RCA's communication satellite business. These studies have included the effect of rain on depolarization of signals on satellite links at 4/6 GHz, the role of companders in increasing traffic capacity on FDM/FM carriers, and new methods for combatting rain fading at 12/14 GHz.

Contact him at:
Communications Research Laboratory
RCA Laboratories
Princeton, N.J.
Ext. 2731

Diversified, cost-effective satellite service for the 80s

J.E. Keigler | D.S. Bond

The first generation of satellite communications systems for North America will mature by 1980. What's in store for the next generation?

After a slow beginning, domestic communication-satellite service in North America is maturing rapidly as an integral component of the total continental communication. Telesat Canada was the first to offer domestic service[1] with their three Anik satellites and widely distributed earth stations and RCA began U.S. domestic service in 1973 by leasing transponder channels on Anik II. Western Union soon followed with U.S. service via their two Westar satellites,[2] similar to Anik's 12-channel design. RCA began operations with its two 24-channel RCA Satcom satellites in early 1976,[3] followed by AT&T's big Comstar satellite.[4] The total capacity of these four 4/6-GHz systems already represents a significant fraction of the continent's long-distance capacity.

Growth to maturity

Growth not only in satellite channel capacity, but in new frequency bands, has begun with Telesat's recent contract for a dual-band satellite to include 12/14-GHz channels in addition to standard 4/6-GHz channels.[5] Likewise, Satellite Business Systems is planning a 12/14-GHz satellite system for direct, digital customer service.[6] Both of these systems are planned for service before 1980.

With the current North American domestic satellite communications systems thus reaching full maturity by the end of this decade, technical and economic planning for the 1980s must encompass a broad spectrum of users. Other than the likely exception of the AT&T Comstar system, intended primarily for message trunking service as a component of AT&T's Long Lines Department, the North American satellite systems of the 80s can be expected to carry a variety of types of traffic and to employ a number of types of earth stations. Carriers will expand their private-line message and network tv distribution services, while also adding new services for smaller users.

Multi-purpose, diversified systems will spread the costs to make service to small users possible without government subsidy. Thin-route and single-channel-per-carrier service will dominate in the northern regions of Alaska and Canada and perhaps even in parts of Mexico. The demand for low-cost, two-way tv for education and medicine has recently led to the formation of the Public Service Satellite Consortium. Direct user service for data transfer, with earth terminals on customer premises, is the *raison d'etre* of the SBS venture of Comsat, IBM, and Aetna. This proliferation of services, traffic volume, and number of earth terminals in the 80s will require economies, not only in investment costs, but also in using the finite resources of orbit and spectrum space.

Some present and future systems

The authors are not endowed with any great gift of prescience. The difficulties of forecasting events in telecommunications—just as in any field of science—are brought out vividly in the writings of Arthur C. Clarke.[7] The major new discoveries, the shrewd application of known technology, and changing economic and social factors all contribute to unexpected applications for earth satellites.

However, if we recite a brief list of developments and applications now being exploited or seriously considered, we may indicate some general direction for the early part of the 1980 decade. The list includes:

Communication common carriers, both international and domestic, have been using satellites for heavy-route long-haul telephone and record communication. Domestic systems especially are sure to proliferate in size and expand in traffic load.

Television program transmission, point-to-point for network program assembly and point-to-multipoint for distribution to broadcast stations or broadband cable systems, will become a major service in the years to come. Multipoint services are now expanding rapidly in Canada and the U.S.

Basic telecommunications to sparsely settled areas, isolated by geography or climate, are now being established. Their further expansion in the Canadian Far North and in Alaska will be discussed below. The services include public telephone, home radio and television reception, communication by video, voice, and data for health-care delivery, and communications for public and governmental functions. Instructional television is another important application.

Data transmission (and other transmissions) directly between earth terminals at users' locations are expected to be employed by large business firms, government installations, and eventually by a multitude of smaller customers. This can lead to the establishment of a radio mail system.

Direct television broadcasting by satellite will initially begin to schools, community centers, villages, and medical centers and clinics. Eventually, distribution to homes is very likely in some countries. This use of direct satellite broadcasting for educational purposes in such needy countries as India was forecast some years ago[8] and was carried out to some degree by the NASA ATS-6 satellite equipment in India.

Reprint RE-23-3-9
A similar version of this paper was presented at the AIAA/CASI Communication Satellite Systems Conf., Montreal, Que., April 5, 1976. This version was updated on October 20, 1977.

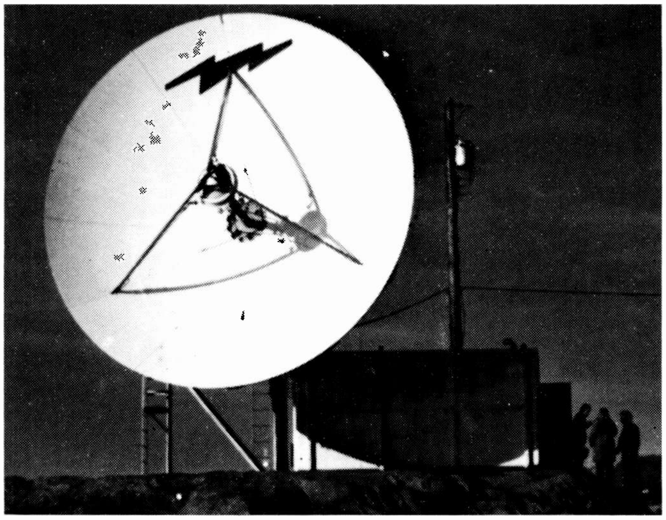


Fig. 1
"Thin-route" earth station at remote Eskimo community of Pangnirtung, on Baffin Island in Canada's Northwest Territories. Unattended station, which provides two toll trunks to the outside world, is part of Telesat Canada system that began service in 1972.

Telesat Canada—the pioneer

When Anik I was launched and put into service in late 1972, a new era in domestic telecommunications began. Telesat Canada's technical and economic innovations have had profound influence on all the subsequent systems that have been planned and put into service. One of the present authors was able to obtain an insight to the potential of satellite telecommunications in serving a sparse population by visits to Telesat stations in the summer and autumn of 1973.

At Frobisher, in the Northwest Territories, the "northern telecommunications" (NTC) station provided multitrunk toll telephone service to the provinces and throughout the North American Integrated Network. It is also brought high-quality CBC television programs to the community. Pangnirtung, a much smaller and predominantly Eskimo community near the Arctic Circle on Baffin Island, uses a "thin-route" earth station to provide two toll telephone trunks to the outside world from a small step-by-step office of Bell Canada. The earth station, illustrated in Fig. 1, is unattended. The quality of transmission and the inherent simplicity and economy of service impressed the RCA visitor tremendously and greatly influenced the current vast RCA program of telephone communications to rural Alaska by earth satellite.

Telesat itself now has about 25 thin-route and larger earth stations for message traffic, and will add at least 10 more in the next two years. Almost all are in the territories (north of the 60th parallel) or the northern part of the provinces.

Television-program distribution by remote tv-receive earth stations was considered highly important in Canada and began in the spring of 1973. Later that year Whitehorse, Yukon Territory was visted. That "remote television" station, which obtains network-quality tv from CBC's Northern Program, is unattended, but receives periodic maintenance by CN Telecommunications. A trip was made to Yellowknife, NWT, over a year later to learn about long-time reliability of the remote tv earth stations. Substantially no outages had occurred—a marvelous record, attesting to the inherent reliability of space communication systems and the excellent engineering of the earth stations by Telesat. At the end of 1975, there were about 45 earth stations in Canada equipped for tv reception, including the two large "heavy-route" stations and the six "network tv" stations in the provinces. Both the latter types are arranged for tv transmission, and several more remote tv stations are planned for the next two years.

Satellite telecommunications for Alaska

Many of the innovations of Telesat Canada are being put into practice in Alaska.

RCA puchased the statewide long-distance telephone network from the U.S. Air Force in 1970, and early in 1971 became the sole long-lines carrier in the state. The Alaska Communications System then consisted of a number of tropospheric links, microwave relay circuits, miscellaneous other terrestrial facilities, and submarine cable. The system was configured principally for military traffic and was suddenly becoming inadequate for the rapidly growing commercial traffic to Alaskan cities. It served very few of the small bush communities.

Early expansion plans by RCA included satellite toll trunks for high-traffic routes from the Anchorage, Fairbanks, and Juneau toll centers to the "lower 48" states. The success of domestic satellite systems in Canada for both heavy-traffic and thin-route applications showed clearly that most of the expansion in rural areas and for interestate traffic should be based on the use of satellite, rather than microwave or tropospheric, systems.

In the two-year period up to the end of 1975, seven 10-meter earth stations of medium to high capacity were installed in Alaska by RCA. These included Lena Point (serving Juneau), Bethel, Nome, Prudhoe Bay, Valdez, Yakutat, and Cordova.

The Alaska "Bush Program" began bringing limited telephone service by satellite to small communities in mid-1975.

A joint undertaking of the State of Alaska and RCA, the program is for small communities ranging in population from 25 to several hundred. Twenty "small" (thin-route) stations were in service by mid-1976, and eighty more are to be installed by the end of 1977. Each will initially provide two circuits, one for public telephone use and the other for a private line or net circuit for the Native Health Aide in the community. The installations are capable of later expansion as traffic warrants.

Each station uses a 4.5-meter-diameter antenna and a low-noise rf amplifier (LNA) of about 200°K equivalent temperature. The overall station G/T becomes about 19-20 dB/°K, depending on antenna elevation angle. Single-carrier-per-channel equipment is used, with at least two modulation methods possible.

Color-television reception capabilities have been added to many of these thin-route stations. NTSC color standards are employed and rf modulation is compatible with that in use in the lower 48 states and Canada to permit reception of

Fig. 2
Telemedicine by satellite experiments in Alaska began in 1974. The two antenna dishes here link the lone nurse at the Alaska Area Native Health Service Clinic at Ft. Yukon with physicians at an Anchorage hospital.

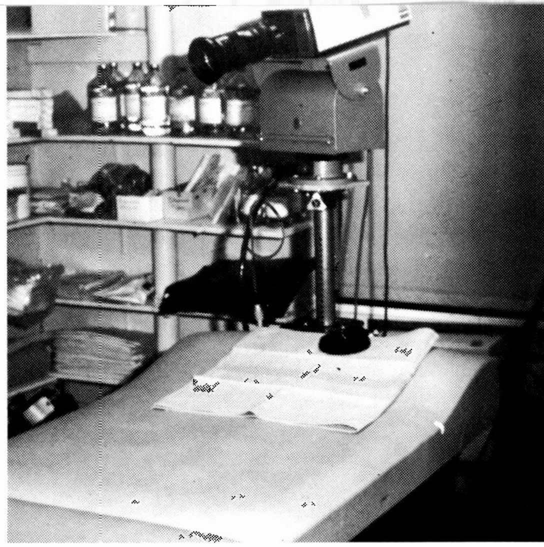


Fig. 3
Telemedicine camera in the examing room at the Ft. Yukon clinic.

direct network satellite feeds. This undertaking is being supported by the State of Alaska. Effective LNA temperatures in the range of 120° K are planned for higher-quality reception at the EIRP values obtained with the RCA Satcom satellite.

Telemedicine is now linking remote Alaskan communities with medical centers.

Telemedicine is now the subject of extensive field tests in the United States. Foremost among the experiments are the recent ones in Alaska using the NASA ATS-6 and the ATS-1 satellites. The Alaska experiments, as well as those in the lower 48 states, include two telecommunication links:

Audio—Two-way telephone service, and, in Alaska, provision for telemetering patients' vital readings or transmitting of health records.

Two-way television—Between physician and nurse or between general-practitioner physician and specialist.

The telemedicine experiments conducted by the Alaska Area Native Health Service in 1974-1974 were most favorable and point the way to the initial operational phase of use of telemedicine for the Alaska Natives. One of the authors became an instant sourdough by visiting Ft. Yukon, Alaska in January, 1975, immediately after the end of a -70°F cold spell that isolated the community for ten days. During that time the health care of the people was entirely in the hands of the one nurse at the Native Clinic. Here telemedicine demonstrated its worth in providing visual contact with the physicians at the referral hospital in Anchorage. (See Figs. 2 and 3.)

Plans are now being implemented jointly by the AANHS and RCA to link the small regional hospital in Bethel and the large Anchorage facility by telemedicine. This involves satellite transmission of full duplex video and voice between the existing RCA earth stations at Bethel and Talkeetna. Many of us feel that current commercial communication satellites (like Anik, RCA Satcom, or Westar) and earth stations like those in Alaska offer telemedicine at vastly lower total cost than via an ATS-6 satellite.

Ultrafax radio mail service

In this proposed new satellite service for the 1980s, we shall not use Alaska as the example, but rather treat the North American market more broadly. In doing so, we are skipping over the application of high-speed digital transmission for a variety of well-known uses, e.g., traffic to and from computers for scientific and business data transfer.

Thirty years ago RCA disclosed a method of radio mail transmission called Ultrafax.[9] Each frame of a tv signal would transmit one page of copy in facsimile form. At standard scan rates, a tv channel could accommodate 30 pages a second or about a million words a minute in analog form. Demonstrations were given in 1948 across the city of Washington, D.C. to the Library of Congress using a 6-GHz microwave link. The expected transmission rates were achieved. As an example, the entire book *Gone with the Wind* was transmitted in slightly over two minutes. It was recorded on 16-mm film and rapidly processed.

The art was not sufficiently advanced then to offer commercial success. With more recent advances, and under the stimulus of rapidly rising costs of physically moving mail, the opportunity is now being reconsidered by several organizations in the U.S.[10] The wheel is being re-invented. The principal new tools are:

1) earth satellites for low-cost long-haul circuits;

2) earth terminals for use on the premises of large users (post offices, large business firms, and government establishments);

3) broadband cable systems (like CATV) to provide channels to small users, eventually including individual households;

4) digital facsimile transmission by PCM for efficient channel use and good half-tone rendition; and

5) improved high-speed facsimile recorders using dry electrophotography and laser and other light sources.

Spectrum and orbit crowding

Bottlenecks are starting to form.

Benefitting from the prior experience of the Intelsat system, domestic carriers in service to date have exploited the 4/6-GHz band, which represented little technical risk. These frequencies had demonstrated transmission characteristics and well-developed hardware technology for spacecraft and earth stations. However, since this frequency band is shared with terrestrial microwave systems whose density is greatest near metropolitan areas, frequency-coordination requirements compelled the typical earth station to be located fifty or more miles from the urban area it serves. Hence a significant part of the cost of domestic satellite service to date is the terrestrial "tail" that connects the earth stations to the urban areas and distributes the signals to the users.

As the number of domestic carriers, their satellites, and their earth stations operating in the 4/6-GHz band have steadily grown, the proper utilization and allocation of the limited spectrum and orbit space have become more important. With its responsibility for frequency and longitude assignments, the FCC, with support by NASA and cooperation of the Canadian Department of Communications, has continuously had to balance the conflicting demands of more satellite "slots" with the desire for lower-cost earth stations using smaller antennas. Advances in component technology for both the output power and directed EIRP of the satellites and the low-noise amplifier of the earth station have made smaller ground antennas technically feasible and attractive to some users, but the larger beamwidth of small-diameter antennas limits the longitude spacing of adjacent satellites.

Although the number of 4/6-GHz satellites planned for North American service by the four carriers now in the business (AT&T, RCA, Telesat, and Western Union) is considerably less than the peak originally requested when the FCC opened its domestic file in 1970,[11] there is still conflict in the optimum central region of 105 to 125° West longitude. NASA's study[12] has indicated that maximum use of the equatorial arc will require not only limiting the minimum earth-station diameter, but coordinating channel frequencies and polarizations of adjacent satellites. While these results conclude that a 1.5-degree spacing of like-polarized spacecraft operating into 10-meter antennas is permissible from an interference criterion, the FCC has not to date allowed orbit assignments closer than five degrees. Firm policy on orbit, frequency, and polarization assignments is unlikely to be established until the demands and conflicts reach the crisis stage.

Several of the satellite communications carriers are taking their own steps to use spectrum and orbit space more efficiently.

AT&T's Comstar and RCA Satcom have introduced cross-polarization techniques to double the number of standard 35-MHz transponders channels per satellite from 12 to 24 within the allocated 500-MHz bandwidth at 4/6 GHz. Not only can other users be expected to eventually adopt dual polarization for similar economic reasons, but the FCC may eventually require it (in a single satellite or two collocated satellites) in order to use the equatorial arc serving North America optimally.

Beam isolation is another technique for spectrum reuse that may find application for domestic service.

It is being introduced into the latest series of Intelsat satellites, and is applicable where distinct geographical areas have different traffic. Severe antenna sidelobe requirements must be attained to prevent inter-channel crosstalk, but the advanced multiple-beam antennas being developed currently for the Department of Defense may provide a practical alternative to the brute-force approach of individual high-gain antennas. Limitations on area coverage, connectivity, and flexibility of channel assignment may pose restrictions on beam isolation for spectrum reuse even if new antenna developments make it technically feasible. However, if these limitations are compatible with a particular carrier's operations, beam isolation not only uses orbit/spectrum space more efficiently, but also provides more effective power utilization because of the higher antenna gain of the smaller beams.

Satellite systems operating at higher frequencies have a number of advantages.

Telesat Canada has recently started its program for operating at 12/14 GHz. In spite of the known susceptibility to heavy rainfall attenuation, this higher band offers three significant advantages to the carriers. First and most important, the band (11.7 - 12.2 MHz space-to-ground and 14.0 - 14.5 MHz ground-to-space) is dedicated to satellite service, so frequency coordination for ground-antenna siting is greatly eased, and antennas can be located in urban areas rather than 50 miles away. Second, with no flux limitations because of shared service, higher satellite EIRP can be used, so customers can use smaller ground antennas. And third, 12/14-GHz satellite locations can be interspersed, or virtually collocated, with 4/6-GHz satellites for optimum North American coverage.

Now that advances in device technology, both for satellite receivers and TWTAs, have made systems in this band technically and economically feasible, both multiband and dedicated 12/14-GHz satellite systems will expand during the 80s as they become the most cost-effective for particular types of users. No North American applications are yet committed, but the 12-GHz band is of course also allocated to direct broadcast satellite service. Three experimental direct broadcast programs are being funded by Canada/U.S., Japan, and Germany. The Canada/U.S. (CTS) Satellite is now in orbit and experiments are being conducted.

While spectrum reuse and multiple bands have eased the strain on the availability of orbit/spectrum space, increasing traffic and demands in the 80s will give rise to standardization for most efficient use of the space. The outstanding question is whether such standards will be voluntarily adopted by the carriers and/or hardware suppliers, or imposed, either by regulation of the FCC and/or treaty via the WARC and ITU.

Satellite system costs

Cost-effectiveness is now paramount.

As the satellite communications industry expands, using all the advances in earth-station, satellite, and launch-vehicle technology that become available, the overriding necessity of cost effectiveness will govern the characteristics of each element of the system. Unbalanced systems, in which overemphasis on low cost of one system element results in extraordinary costs elsewhere, will not thrive, not even with government participation. Although ATS-6 demonstrated the technical feasibility of a high-gain, high-EIRP spacecraft, the government could completely underwrite the cost of more than 2000 ten-meter earth stations operating with a Delta-class spacecraft before reaching the cost of ATS-6.

Launch-vehicle choice affects payload and cost.

For practical planning purposes for operating service during the early 80s, although the space shuttle is pending, there are only three proven classes of launch vehicles for geostationary satellites—the Delta, Atlas-Centaur, and Titan—which have costs approximately in the ratio of 1:2:4. Although their payload weights into final synchronous orbit have the same approximate ratio, and thus their costs per pound of payload in orbit are comparable, it may be neither optimal to employ larger satellites nor desirable to "put so many eggs (or dollars) in one basket" with regard to the risks of successful launch. Of these three launch vehicles, the Atlas-Centaur has been used the most for communication satellites, nearly all for Intelsat. However, the Delta has been the choice of three of the four North American domestic systems, because its lower investment was important to systems having uncommitted traffic load and revenue. As spacecraft designs have become more efficient and the Delta's capability has increased with the 3914 series, it has become the basis for numerous new system plans abroad as well as in North America.

NASA's current plans are to replace all three of these expendable launch vehicles with the space shuttle by the mid-1980s. Shuttle launch costs will be directly proportional to the size and weight of the spacecraft, according to the announced pricing policy. Hence, the preference for minimizing the spacecraft size and weight for a given communications capability will be as much as a driving force in system design in the shuttle era as it is now with expendable vehicles.

The type of spacecraft chosen will also affect cost.

Spacecraft size and cost are approximately proportional to those of the respective launch vehicle. Despite the wide variations in spacecraft configurations and communications payloads, experience to date shows a close correlation between spacecraft weight and total cost per spacecraft, where the total cost includes both initial development and any applicable performance incentives.

As shown in Fig. 4 (derived from published data), this relationship for total spacecraft cost closely follows the first power of spacecraft mass. The cases of noticeable departure from the linear relationship represent either efficient design (below the curve) or unusual development and contractural complexity (above the curve).

Trends in commercial, military, and foreign communications satellites confirm that maximum payload weight and power capacity are provided by three-axis stabilized spacecraft designs as compared to the earlier generations of dual-spin satellites with despun antennas. While the cost per kilogram of an-orbit mass adheres to the relationship of Fig. 4 the communications capacity per kilogram is significantly greater. For example, the channel capacity and EIRP per channel of RCA Satcom is equivalent to that of Intelsat IVA and double that of Anik. Hence, while the dollars per kilogram of all three are nearly equal, the cost per channel of the three-axis stabilized RCA Satcom is appreciably lower.

In addition to the initial spacecraft and launch-vehicle cost, of course, the reliability of each contribute to the life-cycle cost of the system. Launch-vehicle failures are more drastic with the larger spacecraft. With comparable launch-failure probabilities for the Delta and Atlas-Centaur, for example, there is a double incentive to achieve a satellite design compatible with the lower-cost booster, since program cost planning must include launch failure(s) as well as the basic

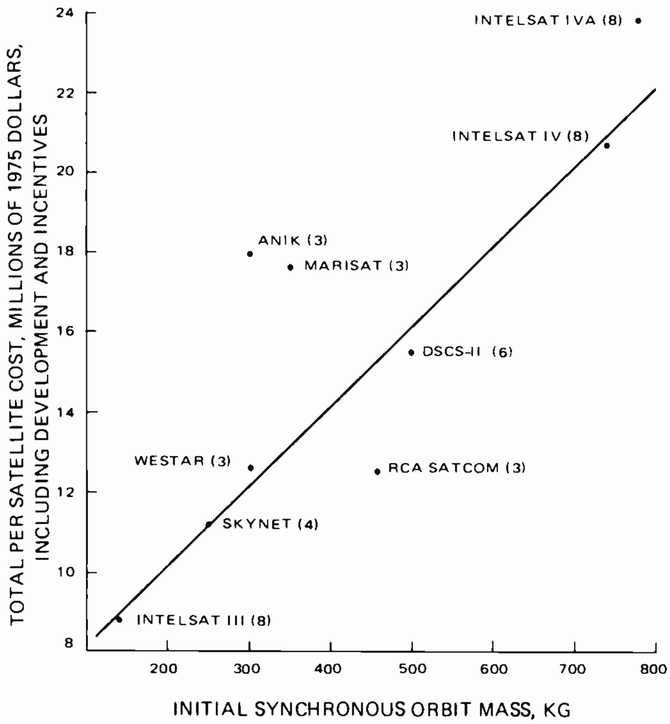


Fig. 4
Total spacecraft cost is directly proportional to spacecraft mass. Note that RCA's Satcom satellites are cost-effective designs.

vehicle cost. Similarly, premature in-orbit demise of the satellite increases the program costs for replacement satellites plus another launch vehicle. To limit the possible financial losses from either launch or in-orbit failures, the carrier may elect insurance coverage, which is another significant cost that must be factored into the total program cost considerations.

Earth-station costs are decreasing.

Earth-station costs are influenced greatly by: the amount and types of channelizing equipment; the number of rf transmitting and receiving channels; the type of modulation employed; the figure of merit (*G/T*) and transmitter EIRP required for voice, television, digital, or other traffic; and other system factors. Thus, it is impossible to directly compare the cost of a large Intelsat earth station with a thin-route installation having only one or two voice circuits. Inflation produces an additional cost bias. The prices of buildings, civil works, auxiliary power supplies, and antenna de-icing equipment (in certain locations) are important parts of system costs. In remote areas like rural Alaska, the freight charges for equipment delivery, installation labor costs, and transportation of field engineers and technicians add up to a disproportionate fraction of the total system cost.

If we look next at thin-route telephone stations for the Far North in North America, we find a steady downward trend in cost as field experience has been gained. Antenna diameters have decreased from about 8 meters to about 4 meters, and certain redundancy has been removed. An analysis of the trade-off of antenna vs LNA performance and costs indicates that for the less favorable sites, where EIRP values may be 32-33 dBW, a reasonable range of preferred antenna sizes for tv is 5 to 6 meters.

Table I
TV-circuit tariffs show cost advantage for satellite system. Local-loop charges are included, as are monthly station commercial changes for the terrestrial carriers.

Facility	*Tariff basis*	*Approximate cost per hour*	*Cost ratio*
RCA satellite	5 hours/day	$ 300	1.0
AT&T terrestrial microwave	10 hours/day	690	2.3
AT&T terrestrial microwave	Occasional use hourly basis	1850	6.2

Table II
Audio-circuit tariffs also show cost advantage that satellite system has over terrestrial microwave systems.

Facility	*Tariff basis*	*Approximate cost per month*	*Cost ratio*
RCA satellite (two-way)	Monthly rate	$ 2,400	1.0
AT&T terrestrial microwave (one-way)	Monthly rate	16,800	7.0

Telesat Canada has developed an advanced design (Anikon), which can be air-transported as a single load in a twin-engine DeHavilland Otter aircraft and then erected on a prepared site, ready for operation in less than eight hours. With the costs of sending an installation crew to a remote site, where living accommodations are nonexistent and where premium labor rates must be paid, the value of the Anikon design is clear.

With somewhat less advanced earth-station package design, RCA is installing the 20 small bush earth stations described earlier, with two high-quality telephone circuits. The average station has a turn-key cost of less than $80-90 thousand. This figure will probably decrease as production quantities rise, as cheaper foundations in permafrost are developed, and as operating and maintenance experience grows.

Diversified-service satellite systems

The competitive pressures in the 1980s can be expected to result in the dominance of satellite systems that have the lowest cost per channel. Except for a few specialized carriers who may operate continuously at virtually full load (e.g., AT&T) or with their particular traffic to a select group of users (e.g., SBS digital business data), the competitive North American systems of the 80s are likely to offer diversified services to a wide range of users. Expanding on the pattern being established by Telesat Canada and RCA Satcom, service costs to all users, including small terminals with only intermittent traffic, will be minimized by employing satellite systems with the flexibility to operate with a variety of types of traffic and earth stations.

It should be noted that satellite systems will have to survive not only the competition with one another, but also with terrestrial systems. The two cases below give side-by-side comparison of satellite and terrestrial costs in commercial service for the tv and radio networks. The sources for the comparisons are published tariffs on file with the Federal Communications Commission early in 1976.

In one case, RCA has contracted to provide a television circuit from Los Angeles to New York City for one of the U.S. networks. The service is required 5 hours every day and is on a long-term contract. Previously this service had been provided by AT&T at either an "occasional use" hourly rate or a ten-hour-per day rate. The satellite system's cost advantage is shown in Table I, which compares the terrestrial and satellite tariffs.

In the second case, RCA is furnishing a program-quality audio circuit via satellite to the same network for service between New York City and Los Angeles. The audio band is from 50 to 8,000 Hz. The circuit was formerly supplied by terrestrial facilities of AT&T with the maximum audio frequency actually limited to 5,000 Hz. The satellite circuit is two-way at no additional charge, to allow for future needs. Table II shows the the comparative costs, which are again to the satellite system's advantage.

We think that the comparisons made here carry a clear message about the economic superiority of long satellite circuits.

References

1. Almond, J.; (Session Chairman), *Telesat Systems*, AIAA Papers 74-451, 452, 453, 454, and 455. AIAA 5th Communications Satellite Systems Conf., Los Angeles, Apr 23, 1974.
2. Verma, S.N.; "U.S. domestic communication system using Westar satellies," World Telecommunication Forum, Geneva (Oct 7, 1975).
3. Napoli, J., and Christopher, J.; "RCA Satcom system," National Telecommunications Conf., San Diego (Dec 3, 1974) and *RCA Engineer*, Vol. 22, No. 1 (Jun/Jul 1976).
4. Rusch, R.J.; "Comsat general domestic communications satellite," National Telecommunications Conf., San Diego (Dec 3, 1974).
5. Thorpe, D.G.; "Evolution of the Telesat Canada system into the mid-1980s," AIAA Paper 76-220, AIAS/CASI 6th Communications Satellite Systems Conf., Montreal (Apr 5, 1976).
6. "Applications of Satellite Business Systems for a domestic communications satellite," filing before the FCC (Dec 1975).
7. Clarke, Arthur C.; *Profile of the Future*, 1962, Harper and Row, New York. (Note Chapter I, "Hazards of Prophecy.")
8. Bond, D.S.; "Performance characteristics of a system for direct television broadcasting from earth satellites," Intl. Conf. on Satellite Communications, London (Nov 22, 1962).
9. Bond, D.S., and Duke, V.J.; "Ultrafax," *RCA Review*, Vol. 10 (Mar 1949) p. 99.
10. U.S. Patent 3,594,495; "Radio facsimile postal system" (Jul 20, 1971).
11. Report and Order "Establishment of domestic communication satellite facilities by non-governmental entities," FCC Docket No. 16495 (Mar 24, 1970).
12. Freibaum, J., and Miller, J.E.; "NASA spectrum and orbit utilization studies for space applications," AIAA Paper 74-434, 5th Communications Satellite Systems Conf., Los Angeles (Apr 22, 1974).

John Keigler (right) led the design team whose work culminated in the present RCA Satcom program and also led the group that developed and tested the Stabilite three-axis control system now used on polar-orbiting and geosynchronous satellites.

Contact him at:
Communication Satellite Systems
Astro-Electronics
Princeton, N.J.
Ext. 2848

Donald Bond, a retired RCA engineer who is a consultant to RCA, has worked extensively in the field of satellite communications.

editorial input

Technical currency —it's money in the bank

Being "technically current" is very important to engineers. We all know it, and the Engineering Information Survey results in this issue prove it.

But exactly what does "technically current" mean...not academically, but in a real-life practical sense to the working engineer at RCA? It is really quite simple: If you are technically current, you are ready to carry out your engineering assignments in today's highly competitive environment! No more, no less. Put another way, you must apply the latest, most cost-effective engineering tools to your present assignment...and be knowledgeable enough about technology to work rapidly into a new product field should your old one become obsolete.

Although the definition of "technically current" appears simple, its implications for the practicing engineer are not. If you're a specialist and an authority in your field—and the products you support are among the best available—doesn't that prove you are technically current? Unfortunately, no. You may have started with the sharpest engineering tools, done creative work, and then, as your products matured and their manufacture was simplified, your challenges diminished and your tools dulled. Now you may be rapidly moving towards becoming one of the world's foremost experts on a product nobody wants, which hardly means being technically current!

The implication is that, to keep technically current, you must overcome the very real obstacles and inertia presented by your daily work assignments and direct sufficient time and energy to the task of learning current technology, gaining working knowledge of new engineering tools and techniques as they emerge, and finding ways to use some of this newly gained knowledge.

To accomplish this, you must go beyond specialty; consider such questions as: How will the new technology affect my product? Will it produce a different kind of product that will obsolete mine? Is is presenting new opportunities for me?

Is it possible to keep technically current in today's environment of enormous information growth? Evidently, yes. Look around RCA; you will see very many examples of key contributors who have made the transformation into one or more new technologies that were completely unknown at the time of the contributor's initial education. And they have innovated new techniques and products in each technology. Unfortunately, there are also too many examples of those who have not kept technically current, whose specialty is no longer useful, and who must leave the engineering field—unable to compete. At this point, it matters little whether the cause was negligence or bad advice—the engineer must face reality alone.

A substantial number of today's engineers were educated in the era of electron tubes. These engineers subsequently learned about semiconductors, and participated in the obsolescence of their earlier products. They saw integrated circuits of increasing complexity challenge discrete transistors and realized that digital technology would tremendously influence electronics. Today, many of these former tube "specialists" are enjoying the challenges and opportunities of microprocessor-controlled product design.

What other profession has had such a task of continuing learning and keeping technically current and the excitement of so many new breakthroughs? How could an engineer survive professionally in the ever-changing electronic technology jungle without keeping technically current next year...and next!

To help you find out how technically current you are, the *RCA Engineer* is publishing a series of papers giving the results of the Engineering Information Survey, beginning with this issue. As you read these papers you can compare yourself with your peers at RCA and possibly discover some effective ways to enhance your technical viability. Remember, it is never too late to improve.

Join and stay with those for whom engineering is an exciting, satisfying lifelong career.

—Hans Jenny

Hans Jenny has experience as a design engineer, engineering leader and manager, and Chief Engineer and Operations Manager of RCA's solid-state microwave product line. His present position of Manager, Technical Information Programs, for Corporate Engineering uses this background to assist RCA engineers in their and the Corporation's efforts to remain viable and competitive. If you have questions or recommendations on this topic, please call Hans at PY-4251, Cherry Hill, or from outside RCA, 609-779-4251.

RCA Globcom's role as a carrier

RCA started out as an international communications corporation in 1919. RCA Globcom has taken that base and expanded it to over 70 times its initial sales with a number of innovative services.

J.C. Hepburn

Overseas telecommunications has gone through a steady stream of evolutionary changes and we are now on the threshold of further transformations. These are evolving from new developments in technology, a growing market for data transmission, the multiplying need for communications services by business and government, and basic revisions in Federal Communications Commission policy. All of these factors will play significant roles in shaping the direction of international record communications in the future.

Over the past two decades, the industry has made significant strides in bringing modern, efficient, low-cost communications to the far corners of the earth, linking both industrialized and emerging nations. You can now reach almost any place in the world by telegram, telex, or on a private line with little more difficulty than you can call across town. In the face of spiraling costs, this expansion has been done with improvements in the quality of service and reductions in the price of these services.

Perhaps the best way to dramatize the differences between rate reductions in international and domestic communications is to look at the ordinary domestic telegram, whose cost has risen by as much as tenfold since World War II. By contrast, internationally, a full-rate message today to most parts of the world costs the same and, in some cases, costs less than it did twenty-five years ago. International telex, which, at the outset of the 1970s, had a minimum charge of nine dollars for three minutes, is now available for a minimum of two dollars for one minute.

How does RCA fit into this picture?

For over half a century, RCA Global Communications, Inc. has been one of the world's leading overseas common carriers, supplying a wide spectrum of services linking the continental United States with a globe-spanning network of telecommunications facilities.

Today, RCA Globcom still performs the basic international communications that was the original function of RCA when it was formed and acquired the Marconi Wireless Telegraph Company in 1919. RCA inaugurated commercial overseas radio communications on March 1, 1920 with messages sent between New York and London. In its first full year of operation, RCA's revenues were $2 million. In contrast, RCA Globcom's 1976 sales were $143.8 million and RCA Corporation reported record sales of $5.4 billion.

Communications facilities

RCA Globcom maintains the world's largest international network of voice/record circuits,* serving more people (comercial users, government agencies, the news media, and the public) in more places than any of the other overseas carriers. Globcom employs high-capacity transoceanic cables, terrestrial microwave systems, satellite systems, and high-frequency radio circuits in a network of more than 2500 telegraph and voice frequency channels which are growing in number each year.

We have invested about $300 million in plant and facilities and employ over 2500 people. The company operates circuits jointly with our correspondents on the global Intelsat commercial communications satellite system and is part owner of the seven U.S. earth stations for that system. RCA Globcom installed, and now maintains and operates, the United States earth station in Guam. To meet projected worldwide communications growth, we are investing approximately $7.7 million in the next few years to expand and extend cable circuit facilities. RCA Globcom has a $5 million investment in TAT-6, the world's highest-capacity, completely transistorized submarine cable, which stretches from Rhode Island to France. The first of RCA's 115 circuits in this newest transatlantic cable was activated in August 1976, connecting the United States with Germany. By the end of 1977, approximately 70 TAT-6 circuits should be activated to points throughout Europe and beyond. The balance of the circuits will go into service as soon as additional capacity is required.

The company is also planning to invest in the proposed Caribbean Cable System, which will link the U.S. mainland with Puerto Rico, the Virgin Islands, Brazil, Venezuela and neighboring Latin American countries. The new cable is expected to be operational by 1978 and will provide the first direct all-cable route to Brazil.

RCA Globcom has historically been the leading U.S. carrier serving points in the Pacific. To maintain this position, we have invested approximately $20 million in TRANSPAC II. This cable system, completed in late 1975, links the U.S. mainland and Japan via Hawaii and Guam and provides service between the U.S. and other Asian countries. Existing and planned cables beyond Japan will connect

*As used in this article, the term "voice/record" includes telegram, telex, leased telegraph channels, alternate and simulanteous voice/data channels, data, and facsimile transmission.

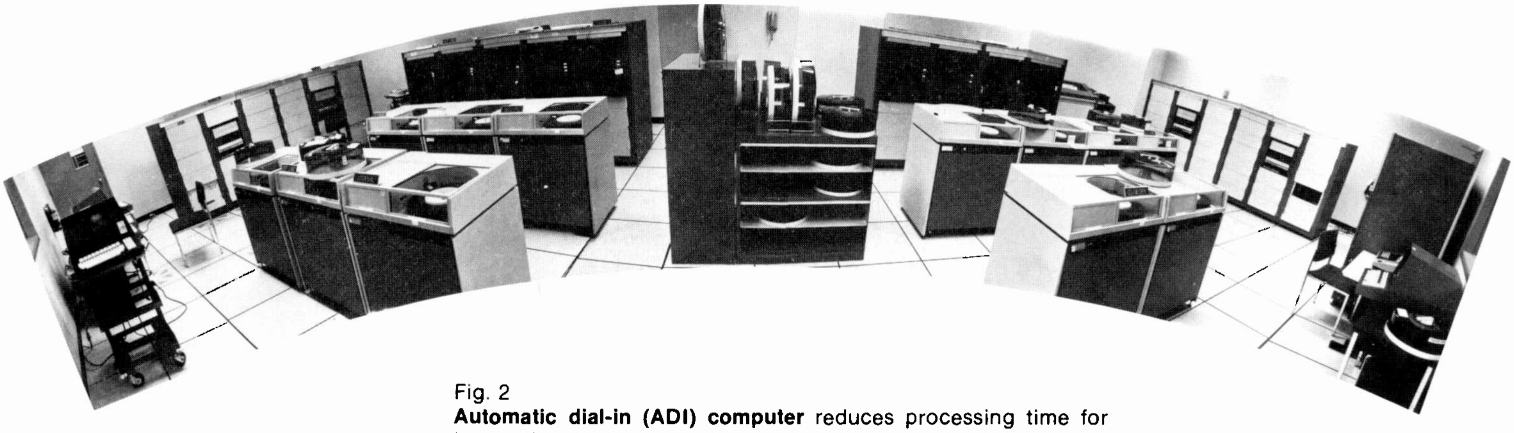


Fig. 2
Automatic dial-in (ADI) computer reduces processing time for international telegrams, also provides instant billing information.

Photo credit: Al Garratt

Taiwan, Hong Kong, the Philippines, Korea, and the People's Republic of China.

RCA Globcom's customers

RCA customers consist of a diverse roster of small and large companies and individuals who require overseas voice/record communications services. These include banks and brokerage companies, oil companies, shipping and freight forwarders, trading companies, importers and exporters, and the automobile, steel, aluminum, copper, rubber, electronics, clothing, and shoe industries. Communications users also consist of brokers in the wheat, cotton, corn, cocoa, and coffee commodity markets, airlines, transportation and insurance companies, and the service industries, such as auto rental, hotels, and travel agents. To these must be added foundations, universities, the world's consulates, state and U.S. Government agencies, news services, and the general public.

Fig 1
Automatic retrieval computer (ARC) is an example of telegram-facility automation. Telegrams for overseas destinations must fit into a proper international format; the ARC automatically removes messages from the Computer Telegram System (CTS) that are not in the correct format and displays them on this CRT monitor. Operators make needed corrections and then route the telegrams back to the CTS.

Competitors

While RCA Globcom is a leader among the overseas voice/record carriers operating in the United States, its competitors for overseas business are: ITT World Communications Inc., Western Union International, Inc. (not affiliated with the Western Union Telegraph Company), TRT Telecommunications Corporation, United States-Liberia Radio Corporation, and the French Telegraph Cable Company. In addition, the American Telephone & Telegraph Company has a monopoly in the international voice-only communications business. The FCC recently also authorized two former domestic-only carriers, Graphnet Systems, Inc. and Telenet Communications Corp., to provide international service, but this is being contested by the major carriers.

Basic services

RCA Globcom's principal overseas communications services include: telegram, telex, private-line teleprinter and simultaneous and alternate voice/data channels, facsimile transmission, program broadcast, television transmission and reception, worldwide marine services, and telephone service between Guam and over a dozen other Pacific points.

Message telegram, the oldest and probably the best-known of the services, began in the Morse-code era long before the advent of modern electronic communications.

RCA Globcom was first in the industry to automate the handling of international telegrams with a Computer Telegram System (CTS). This system uses an array of electronic data-processing equipment that automatically receives, audits, routes, and transmits telegrams across the world in fractions of a second. Before the computer, the same operations took several minutes.

A later auxiliary addition to this system, the Automatic Retrieval Computer, or ARC (Fig. 1), takes telegrams that U.S. customers have not filed in the proper international format, electronically converts them to the proper format, and feeds them to the CTS.

RCA Globcom has now nearly completed a high-speed second-generation computer system that will provide an

Photo credit: Al Garratt

Fig. 3
Computer telex exchange (CTE-II) handles over 80% of the overseas telex calls sent through RCA. System increases speed and accuracy of telex calls, also adds a number of convenience features.

input-output capability more than 100 percent greater than that of the CTS and ARC and will further reduce handling costs. A segment of the new system computer, a high-speed automatic dial-in computer (Fig. 2), has recently been activated in the Kingsbridge Communications Center, in Piscataway, N.J., further reducing the processing time of overseas telegrams to more than 230 overseas destinations.

Telex is a subscriber-to-subscriber dial-up teleprinter service.

It enables a customer in the United States to transmit and receive messages to and from any overseas correspondent, directly over private teleprinters in his office. Customers can literally "talk in writing." From 1964 to the early 1970s, overseas telex grew at the rate of approximately 30 percent annually, and since 1967 has replaced the telegram as the primary source of the industry's revenues.

RCA Globcom now has direct telex service with more than 185 overseas points and connects U.S. subscribers with teleprinters in any of hundreds of thousands of offices around the world. Since Globcom introduced telex service in 1950, the number of calls handled by the company has risen dramatically from 1500 in the first year to 27.2 million in 1976.

Telex has become popular with users for a number of reasons. For the small importer and exporter, the international telex or telegram message offers the fastest and most positive means of negotiating price, obtaining delivery dates, and providing the information necessary to expedite clearance of imported goods through customs.

Record communications can frequently solve many of the problems of placing business calls intercontinentally during non-coincident business hours. For telephone users, the greater the difference in time zones, the greater the problems. In some places overseas, there are so few telephone circuits available that placing a business call often requires a long waiting time. Selecting telex can produce contact almost immediately. And, telex is in written form, which can be handled at once, or as soon as the office opens, with reduced chances for misunderstanding.

To handle the proliferating number of telex calls, RCA Globcom installed the industry's first computer-controlled telex switching system. Using area codes and numbers similar to those for making long-distance telephone calls in this country, subscribers can make direct-dial telex calls overseas without operator intervention at any point. Today, our subscribers and, by direct interconnection with our facilities, those of Western Union's domestic telex and TWX networks, can reach more than 90 percent of the world's teleprinters by this automated system.

In addition to increased speed and accuracy, the computer system provides an array of customer convenience options:

Uni-codes make it possible to dial the most frequently called customers' numbers by just typing a single digit. With this setup, calls go through faster and with less chance of error.

Automatic camp-on keeps trying a busy telex number for about 3 minutes until connection is made.

Telextra automatically takes a call into the computer when the circuits are busy and delivers it when the line is clear. It provides confirmation soon after the call is cleared.

Stay-connect lets a subscriber call another number when he gets a busy signal; he doesn't get cut off and have to make another connection.

Telexgram takes an undeliverable telex call and converts it to a telegram for easy delivery.

Multiple-address service sends the same text to many overseas locations quickly and automatically.

Departmentalized billing gives customers monthly charges for overseas telex calls by department in subscribing companies.

In late 1975, a completely new Computer Telex Exchange, CTE-II, (Fig. 3) went into operation at the Kingsbridge Communications Center in Piscataway. The new system was further expanded in 1976, with additional redundant subsystems, increasing both capacity and reliability.

The CTE-II is now handling over 80 percent of RCA's daily volume of overseas telex calls. When the CTE-II installation is fully expanded, it will have three times the trunk-handling capacity of the original computer system. The new system has the modular capacity to handle growth requirements to 1980.

Fig. 4
Computerized message switching system for leased-channel subscribers is called AIRCON. System handles high-speed traffic, giving urgent traffic priority and selecting alternate routes if the original route is interrupted.

Leased channels are essentially private lines that permit U.S. subscribers to maintain direct, uninterrupted communications with locations throughout the world.

RCA Globcom installed the first commercial leased channel in 1948 and still leads the industry today, with leased channel service to over 100 overseas points. RCA Globcom has approximately a 43 percent share of the total industry leased-channel business.

When a customer leases a channel from Globcom, the company arranges for everything, including all the necessary communications equipment at both ends of the channel. Globcom also assumes end-to-end responsibility on a continuing basis for optimum performance.

RCA Globcom provides both narrowband teleprinter channels and wideband or voice-grade channels, which make possible a choice of communications modes, alternate voice/data, or facsimile with simultaneous teleprinter service.

Wideband circuits can transmit data at speeds up to 9600 bits per second. As many as 24 standard-speed 100 word-per-minute channels can be derived from one voice-grade circuit, or a lesser number of channels can be provided for high-speed printers.

A typical leased-channel application is the digital facsimile service provided for the National Oceanic and Atmosphere Administration (NOAA). RCA Globcom furnishes NOAA with the overseas voice-grade circuit that links the National Weather Service in Maryland with the Central Forecasting Institute in Moscow for regular interchanges of meteorological information. This circuit supports the U.S. Weather Bureau participation in the World Meteorological Organization, which contributes to the safety and comfort of intercontinental air travel.

Computer-to-computer communication is increasing.

RCA Globcom is now offering 50-kilobit/s overseas leased-channel service for point-to-point transmission of large volumes of information. The service is carried overseas by satellite and is designed for real-time computer-to-computer communications.

RCA Globcom is a major supplier of high-speed digital data services that link the NASA tracking stations and switching centers around the world. At the end of last year, three 50-kb/s wideband circuits were in operation supporting scientific space programs and projects for NASA. While NASA is presently the major user of these facilities, 50-kb/s service also has broad application for high-volume users.

AIRCON is a shared computerized message-switching system for leased-channel customers.

Introduced by RCA in 1967, AIRCON permits companies having their own private teleprinter networks to plug into a master computer for automatic relaying of messages. AIRCON switching centers (Fig. 4) in New York and San Francisco direct information flow and interconnect the overseas and domestic offices of high-volume subscribers who need a rapid exchange of information.

One of the most successful AIRCON applications can be seen in the petroleum industry, which uses the switching system to exchange refinery production data, tanker routes and schedules, crew assignments, cargo manifests, and a variety of administrative information between widely separated U.S. and overseas locations.

AIRCON computers continuously channel messages to their destinations and ensure that high-priority messages are transmitted first. The center routinely handles thousands of messages a day.

Recent additions to service

RCA Globcom is now offering Mailgram service to Hawaii.

This service, now offered on an interim basis, enables customers in the U.S. mainland and in Hawaii to send messages between these points for local delivery by the United States Postal Service. The company has also requested authority from the FCC to initiate permanent electronic mail service (EMS) between the U.S. mainland and other overseas operating points. The company plans to use its existing facilities and those of the United States Postal Service for the new electronic mail service. The proposed EMS is similar to service provided domestically, which uses a combination of telegram service and mail.

Worldwide marine communiations via satellite became a reality with the inauguration of Marisat service by RCA Globcom in 1976.

For the first time in marine history, ships at sea can enjoy almost instantaneous two-way worldwide telegram, telex, voice, data, and facsimile contacts with shore points. Communications via the Marisat satellites make this possible. Two Marisat satellites are operational over the Atlantic and the Pacific areas. The third "bird," in orbit over the Indian Ocean, will be used primarily by the U.S. Navy.

RCA Globcom is the only Marisat carrier that can provide total marine communications to subscribers: sale or lease of shipboard terminals, satellite communications services, and conventional high-frequency, high-frequency cw, and high-frequency teletype radio service.

In 1976, the FCC designatedMiami and New Orleans as full-service "gateways" for RCA Globcom.

The new gateway offices in Miami and New Orleans now give a greater number of subscribers direct access to the full range of Globcom's overseas services with significantly improved quality and speed. The new gateways are part of a proposed expansion program in which Globcom requested authorization from the FCC to provide additional overseas communications services directly to customers in important U.S. metropolitan areas. Globcom previously had full gateway operations in New York, San Francisco, and Washington, and served private-line customers from Miami.

RCA Globcom also performs several other communications-related activities through a wholly-owned subsidiary, RCA Globcom Systems, Inc.

For example, Joint User Service (JUS), a domestic low-speed teleprinter and data network that went into operation in July, 1973, became part of Globcom Systems during 1976. JUS can handle line speeds from 50 to 300 baud.

Another activity,Communications Network Management Service, maintains customer-owned or -leased modems (modulator and demodulator equipment) and multiplexers, which make simultaneous use of a large number of channels on a single circuit possible.

The future

While the overseas communications industry has been established for over half a century, today's dynamic upheavals may produce fundamental changes in its traditional operations. The changes are being triggered by basic revisions in Federal Communications Commission policy, by significant developments in technology, and by the expanding need for international data communications.

RCA Globcom recently established a new Data Service Development group, whose mission is to produce new offerings to meet the user needs of, and so capture a share of, the emerging data-services market.

The company has concluded a series of overseas transmission tests between New York and Tokyo on a new high-resolution, high-speed digital facsimile system that delivers a typewritten page in about 26 seconds. The new system, called "Quick-FAX," and produced by a Japanese company, can send approximately two pages of typewritten material or engineering drawings in the same time that the fastest existing equipment takes to send one page, while simultaneously providing a superior reproduction. The tests definetely point to ways of improving the speed, quality, and cost of public overseas facsimile communications; plans are being examined for offering this service on a commercial basis.

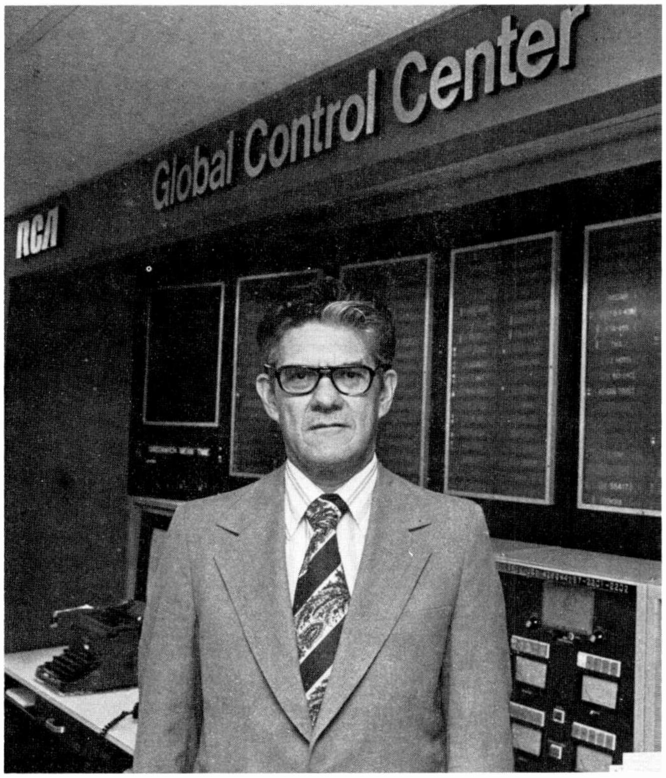
RCA Globcom has also concluded agreements with domestic record communications carriers, subject to the approval of the FCC, to interconnect facilities for the delivery and receipt of overseas data and messages. The agreement with one of the carriers provides packet-switched data-communications service between the U.S. and overseas points. The new packet-switched service is designed as an economical means of communications among computers and a wide variety of terminals operating at low and medium speeds. The primary users of this service are expected to be multinational corporations, public data banks, and commercial computing-service bureaus.

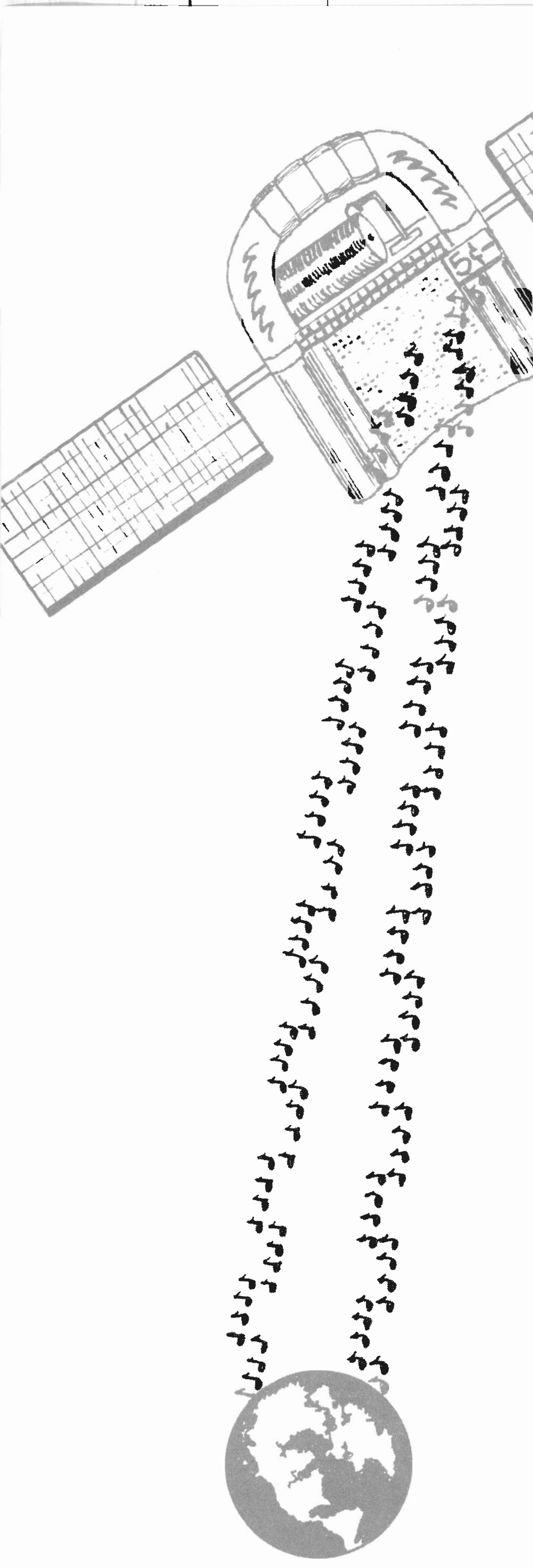
These recent developments point toward RCA Globcom's new directions in the communications field. The company is committed to its pioneering and innovative role in the industry, introducing new services and expanding its plant with the addition of advanced-design equipment and transmission paths.

Reprint RE-23-3-8
Final manuscript received June 17, 1977.

Jim Hepburn is Vice President and Technical Director of RCA Globcom. He joined RCA Globcom in 1941 and served in various operations and engineering posts before becoming Manager, Equipment Design, and later Chief Engineer. He has also been Manager, Pacific Coast; Vice President, Pacific Coast; and Vice President, Operations.

Contact him at:
RCA Globcom
New York, N.Y.
Ext. 7544





Digital processing of music for satellite communication

How do listeners react to different methods of encoding and modulating music?

The success of RCA's entry into the domestic satellite communication market requires careful consideration and planning to provide an economic, flexible communication system that can accept a wide variety of signal types. A prime factor needed for success is the selection of the most efficient method of encoding and modulating the various audio, video, and data signals to ensure a given quality of service with minimum power and bandwidth.

Advantages of digital transmission

Historically, audio and video have been transmitted by various modulation techniques in which the transmitted carrier is a continuous function of the message waveform. However, the development of semiconductor devices over the past twenty-five years has permitted the rapid growth of digital communication systems, in which the information appears in discrete steps of both time and amplitude.

Digital systems have a number of inherent advantages. They provide a more flexible channel in that various kinds of signals—audio, video, or data—can be intermixed in time without impairing each other. This is a valuable asset because the channel then can accommodate various mixes of traffic loads. Digital signals are less susceptible to channel noise, and furthermore, terminal noise and transmission-media noise can be considered separately. The quantizing noise introduced by the digitizing process can be made as low as desired by the choice of the codec (code-decode) transfer characteristic. Transmission-media noise does not build up in terrestrial circuits because regenerators, rather than amplifiers, are used to restore the digital signal. The rapid advances in semiconductor technology and LSI make digital processing attractive because of size and cost reduction. Digital signals are also simpler to encrypt and so reduce security problems. In the future, as digital switches become more prevalent, all-digital telecommunication transmission systems will be developed.

Digital processing methods

A number of practical audio systems are now in existence.

For example, the T1 digital telephone system was introduced about 15 years ago to increase the capacity of interchange trunks in densely populated areas. This system provides 24 channels at 1.544 Mb/s on a single twisted pair of wires. More recently, a rural-subscriber loop carrier system providing 40 channels has been introduced. This digital system uses an adaptive delta modulation technique to encode the voice signal. Digital telephone transmission has now developed into a complete hierarchy of systems, both in this country and in the international network. Higher-speed systems using bit rates of over 100 Mb/s are under development. Another application of digital transmission is the multichannel music-distribution system used on the Boeing 747. In this system, fifteen high-fidelity channels and control information are distributed to each seat on a single coax cable at a data rate of about 5 Mb/s. Digital video is still in the development state, but some systems have been demonstrated. Low-resolution Picturephone service has been provided on an experimental basis using 6.3 Mb/s.

The rapid expansion of digital techniques and digital signal processing makes them a prime contender for satellite communications. At present, most satellite circuits employ continuous-time waveform modulation, but Intelsat has introduced a digital system called SPADE for low-volume telephone circuits.

One of the concerns in selecting a digital system over analog is signal quality.

Although the signal-to-noise ratios can be determined from objective measurements, listeners perceive digital and thermal noise differently. In this paper we describe some digital processing techniques and give the results of a subjective evaluation of the quality of high-fidelity music received over these various systems.

Before discussing specific systems, a brief description of digital processing may be helpful. A digital signal is defined by both time and amplitude. The sampling theorem requires that samples be taken at twice the highest frequency in the band with pulses of zero width, and that an ideal lowpass filter be used to eliminate high-frequency components. In practice, realizable lowpass filters require a guard band, provided by some over-sampling. The T1 telephone system, with sampling at an 8-kHz rate, provides a useful channel bandwidth of 3.5 kHz. The sample pulsewidth should be less than 10% of the sampling time to avoid frequency distortion of the reconstructed signal. In most digital processing systems, the original continuous-amplitude time-sampled signal is converted to a number of discrete amplitudes by a coder.

The simplest coding method, pulse code modulation, divides the sampled signal into a number of equally spaced levels.

PCM, as it is known, produces a staircase approximation to a linear distortionless function. The error between the staircase and the linear characteristic produces signal-related quantizing distortion that is perceived differently from the more familiar random thermal noise developed in analog channels. The quantizing noise can be made as small as desired by increasing the number of quantizing levels. However, this increases the number of bits required to encode the signal, and consequently, the bit rate and bandwidth required for the channel.

Many variations of PCM have been proposed to compress the amount of information that must be transmitted.

For signals that have correlation between samples, as with audio and video, differential pulse-code modulation (DPCM) has been effective for bit-rate reduction. Instead of encoding the direct sample, the difference between the input sample and a predicted signal, based upon past samples, is coded. When the difference signal is coded into one binary bit, the process is termed delta modulation (DM). In this case, the output bits convey the polarity of the difference signal. In ordinary DM, the decoder moves the output signal a fixed increment up or down, depending upon the bit stream.

Companding reduces quantizing noise without reducing step size excessively.

In both DM and PCM, the step size affects the level of quantizing noise. In DM, the dynamic range is limited by quantizing noise and slope overload distortion. If the steps are small, the quantizing noise is low, but a very high sampling rate would be required to follow a rapidly changing signal. On the other hand, if the sampling rate is too low, the received signal cannot accurately follow the rapidly changing signal. DM coders that incorporate a variable step size, which is essentially a companding operation, are called adaptive delta modulators (ADM).

In PCM a similar problem exists. If the quantizing steps are made very small to reduce the quantizing noise, the number of bits per sample becomes large. For example, for linear quantizing steps, 12 bits per sample are required to provide about 70 dB S/N_Q. The number of levels, and hence the number of bits per sample, can be reduced by using unequal level spacing. This reduces the bit rate without reducing the perceived signal quality. A form of companding, it essentially compresses the transmitted signal and then expands the received signal. This method increases the size of quantizing error for large signals and reduces it for small signals, and so in effect yields a constant signal-to-quantizing-noise ratio over a wide dynamic range.

Optimum companding functions are different for different kinds of signal distributions. For example, audio signals require a logarithmic compression function that produces a quantizing distortion proportional to the signal level. For telephone systems, two modified logarithmic functions are in use. In the U.S.A., "μ-law" compression is frequently used, whereas in Europe an "A-law" function is more common. The functions are

Dick Klensch has worked in a wide variety of research projects since joining RCA Laboratories in 1952. His work has included microwave, television, communication, and display systems. He has been doing research in satellite audio and video communication techniques since 1975.

Contact him at:
Communications Research Laboratory
RCA Laboratories
Princeton, N.J.
Ext. 2909

Ed Rogers has a wide research background. He began his work at RCA in 1945 in acoustic and ultrasonic research, then worked on machine recognition and synthesis of speech, and more recently has done system analysis and design. He is now investigating the system aspects of broadband information systems covering data, speech, audio, and two-way CATV systems.

Contact him at:
Communications Research Laboratory
RCA Laboratories
Princeton, N.J.
Ext. 2226

Authors **Klensch** (left) and **Rogers.**

similar at high levels, but the A law becomes linear at low levels. The μ- and A-law characteristics have been developed for speech, with typical values of $\mu = 225$ and A = 100. Fig. 1 gives graphs of several companding functions. For music, a logarithmic characteristic (the curve at the top of Fig. 1) was used with various numbers of levels of approximation. A μ-law characteristic with $\mu = 1000$ is shown for comparison.

All of the digital signal processors outlined above are candidates for satellite communication systems. Digital satellite telephone systems are now in use. One, Intelsat's SPADE system, uses a 7-bit A-law companded PCM codec with a bit rate of 56 kb/s. This signal is compatible with the T1 terrestrial digital hierarchy.

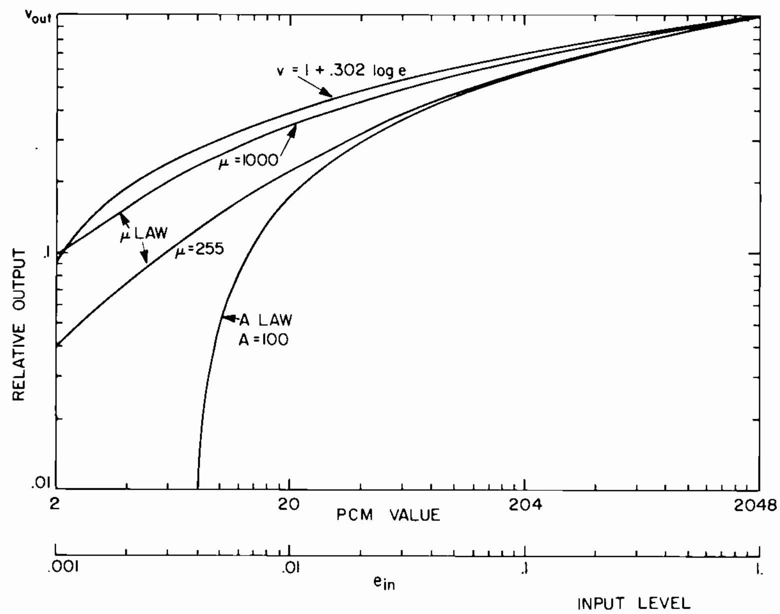


Fig. 1
Companding functions reduce sampling bit rate without reducing perceived signal quality. Different companding functions are used for different signal distributions: curve at top is used for music; "mu" and "A" characteristics are modified logarithmic functions used for telephone systems in the U.S.A. and Europe, respectively.

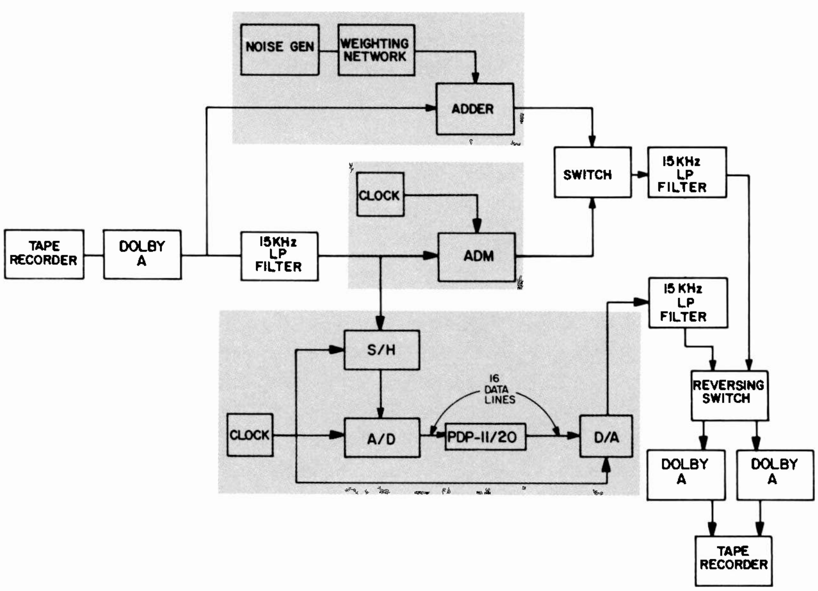


Fig. 2
Experimental test arrangement provides three signal types for listener evaluation after starting with the same high-quality input (left). FM signal (top) is produced by adding weighted noise to the analog channel. ADM signal (middle) is produced by a codec capable of operating at varying bit rates. PCM signal (bottom) is produced by putting analog signal through sample-and-hold circuit, analog-to-digital converter, computer processing, and digital-to-analog converter.

Evaluating the digital processing methods

Although speech, video, and data dominate the current interest in satellite communication, there is a possibility of providing high-fidelity music channels for radio broadcast networks in the future. A number of subjective evaluations have been reported to determine the value of various digital techniques for speech systems, but there does not appear to be any information on subjective evaluations of music transmitted over digital systems. Therefore, the experiment described here was performed to compare the processed music signal received over analog and digital circuits. The digital processors were ADM, PCM, and companded PCM. The output from these processors was compared with an analog signal simulating the type of signal and noise received from a conventional FM receiver.

All three processing circuits (FM, ADM, and PCM) were set up simultaneously so that pairs of processed signal variations could be selected for encoding on parallel tracks of a high-quality dual-channel tape recorder.

Dolby noise reducers were included to provide a test tone-to-noise ratio of 70 dB at a test-tone level producing 3% distortion. Fig. 2 gives a functional diagram of the arrangement. The analog signal source is shown at the left. An FM signal was simulated through the top channel by adding various amounts of weighted noise to the analog signal. The signal to the digital processors was band-limited by the 15-kHz lowpass filter (to prevent aliasing). The response of this filter is 3 dB at 15 kHz and 50 dB down at 16.5 kHz. The band-limited signal at the output of the filter is split and sent to both the ADM and PCM processors.

The ADM codec is a hardware realization of a design developed at RCA Laboratories by W.G. McGuffin. It uses an adaptive processor to adjust step size and is capable of operating at rates between 50 and 300 kb/s.

The PCM processing system is the bottom channel in Fig. 2. This channel employs A/D and D/A converters in conjunction with a PDP-11/20 minicomputer to produce various companded PCM signals. The band-limited signal from the filter is adjusted to provide a maximum level of ±10 volts at the input to a high-precision sample-and-hold circuit. The precision of the sample-and-hold circuit is specified as an aperture uncertainty, which is related to its response-time uncertainty. It should have a value suitably small, consistent with the highest rate of change of the input voltage and the number of bits to which the input will be digitized. This can be expressed by:

$$[d(V \sin 2\pi ft)/dt][A] \leqslant [V(n-1]$$

where
V = peak input voltage
f = maximum input frequency
n = total total number of bits
A = aperture uncertainty

An 0.2-ns aperture uncertainty is therefore just adequate to sample a 15-kHz audio signal with 16-bit accuracy.

The choice of the number of required bits resulted from the signal-to-noise goals and evidence indicating that somewhere between 12 and 14 bits are necessary for "high fidelity." The availability, at reasonable cost, of a 16-bit A/D converter having an 8-μs conversion time made it possible to go beyond what the most critical listeners had indicated was mandatory for complete freedom of quantization effects. Indeed, experiments made with the D/A converter connected directly to the 16-bit A/D converter, whose filtered output was compared to the original unsampled high-quality analog input, demonstrated that 12 bits was good enough for most recorded sound. It should be noted that any number of bits (up to 16) could be selected by the use of toggle switches.

The PCM system described provides a flexible facility for real-time processing of high-fidelity audio. Assembly-language software, provided by S. Calo, allows several options for effecting different companding laws by providing computer-generated translation tables with linear, log, or mixed linear/log characteristics. Tables can also be generated in a "free" manner by inserting the table values from the teletype terminal. Companding is performed in real time by table look-up at a maximum sampling rate of about 33 kilosamples/s. Because of the limited memory capacity of the PDP-11/20, the

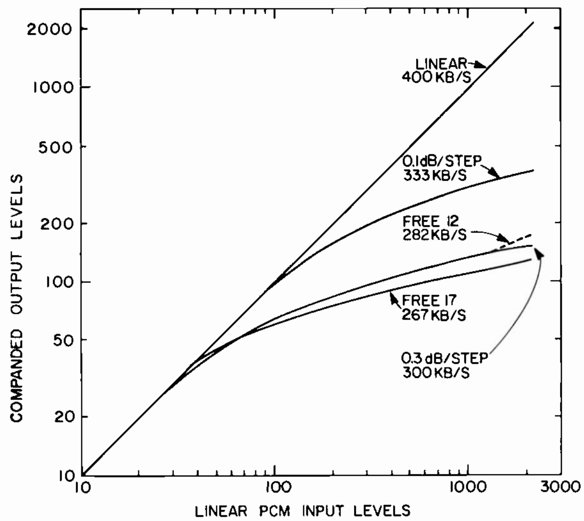


Fig. 3
Five PCM codes were used in the listening experiment. Linear 400 is a 12-bit linear code (11 level bits plus sign bit), 0.1 dB/step codes use pure log companding down to the point where linear size limits companding, and free -12 and -17 use semifree companding with linear, 0.2-dB, and 0.4-dB steps.

16-bit samples from the A/D converter were truncated by the computer to 12 bits for the translation table.

The experiment compared five PCM, three FM, and two ADM signals.

About 25 variations of companding based upon the top curve of Fig. 1 were tried for preliminary tests, and after considerable screening, five PCM encoding plans were selected for final testing. One was linear with 12-bit samples and the other four were companded codes with 10, 9, 8.5 and 8 bits per sample. Assuming a sampling rate of 33.3 kilosamples/s, this results in bit rates of 400, 333, 300, 282, and 267 kb/s. The distribution of levels for these five PCM codes are shown in Fig. 3.

Three FM signal-to-noise ratios and two ADM bit rates were chosen for comparison with these PCM signals. The "quality factors" were 60, 50, and 40 dB S/N for the FM signals and 200 and 300 kb/s for the ADM. This total of 10 different processing techniques for evaluation gave 45 comparison pairs for the balanced test.

Subjective evaluation

Subjective evaluation has been frequently used to measure the relative preference of things that cannot be measured objectively, but with various degrees of success. A number of accepted methods are available, depending upon the purpose of the experiment. Our primary objective in these tests was to rank the various systems without attempting to determine the psychological factors underlying the judgment.

Two methods were used simultaneously in these tests.

In the primary test, listeners were given pairs of recordings and asked to make a preference judgment with a forced decision. In the second test, listeners were asked to rate the recordings on a five-level scale graduated from excellent to not acceptable. The goal of this experiment was to provide information that could be used to estimate the minimum bit rate, and hence bandwidth of a digital channel, that would provide high-quality audio perceptually equivalent to that obtained from a given analog channel.

The test material was chosen to provide a full range of music types—it included solo instruments, small groups, jazz bands, and classical orchestras.

Excellent third-generation master tapes of five stereo albums were provided through the courtesy of RCA Records. Since the original stereo tapes were recorded with the Dolby noise-reduction system, they were "de-dolbized," mixed, and then rerecorded monaurally for test samples. After screening tests were performed to obtain selections that produced noticeable differences between systems, the following selections were chosen:

1) Guitar, Chet Atkins, "Godfather"
2) Guitar, Chet Atkins, "Sting"

3) Trumpet, Buddy Rich Band, "Something"

4) Chicago Symphony Orchestra, "Mahler's Symphony #4"

5) Jazz, Basie Trio, "O.P."

These selections provide a wide range of physical and psychological factors, such as loud-soft, full-thin, and dynamic attributes.

A two-minute test sample was made, using 24 seconds of each selection. This test sample was then used as source material for the system comparisons. The outputs from the various processing systems were arranged in pairs, cut up and reconstructed with a random sequence of 45 two-minute test segments that were evaluated in three half-hour listening sessions.

A heterogeneous group of 35 listeners, made up of males and females covering a wide range of ages, was selected at random from the laboratory personnel. There was no training period involved in these tests, but some listeners were scientifically oriented and presumably may have used special clues for judgment. After some initial analysis of the data, the overall group (A) was divided into two sections, with 20 listeners classified as unskilled (U) and the remaining 15 listeners classified as skilled (S).

The prerecorded test tapes were played for the listeners through high-quality headphones. Each listener station had a volume control and switching between channels. Headphones were used, rather than loudspeakers in a living-room environment, because the program level required to provide a 60-db S/N in the rooms available would have been excessive.

Results

In general, preference testing of several objects simultaneously generates two possible problems. First, are there significant differences between the systems that can be uniformly judged by a group of listeners? It is not clear that this criterion is satisfied when comparing analog and digital systems; it may be like comparing apples and oranges. Second, are the listeners consistent in their judgment of preferences? If the systems are not significantly different, then the data can be inconsistent and circular trials develop in which 1 is preferred over 2, 2 is preferred over 3, and 3 is preferred over 1.

Table I
Ranking of processing methods puts FM and PCM at top; see Fig. 4 for graphical interpretation of data.

Preference % A	U	S	*Processing method*	*Data rate (kb/s)*	*S/N (dB)*
75	77	74	PCM	400	—
73	73	74	FM	—	60
71	74	67	FM	—	50
67	67	66	PCM	333	—
47	49	44	FM	—	40
39	39	39	ADM	300	—
39	35	43	PCM	300	—
38	37	41	PCM	282	—
35	33	37	PCM	267	—
16	16	15	ADM	200	—

To rank the various systems on some kind of a relative preference scale with known confidence intervals, the data from the listening tests was collected in matrix form showing the percentage of time the column stimuli A was preferred over the row stimuli B. The data was subdivided by selection number and listener group and then summarized by a tournament method in which the total number of times a particular stimuli is preferred over all other stimuli is summed and used as a ranking score. The ranking of the various systems by this method is shown in bargraph form in Fig. 4. The scores for each selection (numbered from left to right) are shown in clear bars and the combined results for the five selections are shown as solid bars. Although this method does not indicate the statistical significance, it shows dramatically the effect of the selection and processing method. The data is shown grouped by processing method rather than preference rank. Apparently selections 3 and 4 were preferred on the lower-bit-rate PCM. However, selection 3 had a very low preference on the ADM. The rank ordering from the combined average matrix is given in Table I.

The category-judgment subjective evaluation produced an independent preference ranking; Fig. 5 gives a summary of the mean, μ, the standard deviation, σ, and the 95% confidence intervals. There is no significant difference between FM with 60-dB and 50-dB S/N and 400-kb/s PCM; however, these three are significantly better than all of the other systems. This test method ranks the ADM higher than the ranking obtained from the paired-comparison tests. The figure shows very little significant difference between FM with 40-db S/N and the other digital processing methods.

Conclusions

The evaluation test shows that listeners perceive very little difference between an FM signal with 60-dB or 50-dB S/N and a 400-kb/s linear PCM signal.

Both the paired-comparison method and the category-judgment test showed remarkable consistency in ranking. The processing systems used in these tests were the best ten selected from many trial systems evaluated in preliminary screening tests. A study of Fig. 4 shows considerable variance due to music selection—it appears that the greatest discrimination resulted from the purer, clearer solo instruments and less distinction was obtained from the large jazz bands and orchestras. This is because the broad audio spectrum produced by many instruments masks the distortion introduced by the digital sysem. Vocal selections did not provide much distinction between systems.

There is no question that digital processing sampled at the Nyquist rate produces considerable distortion. This can be reduced by oversampling, but it is impractical because of the excess bandwidth required. When reproducing pure tones, digital systems are unquestionably inferior to analog systems; however, for various other types of music, digital systems can be quite acceptable.

A rough comparison shows that the FM and PCM bandwidth requirements are equal.

The prime purpose behind the subjective evaluation was to determine the power and bandwidth required to transmit a given

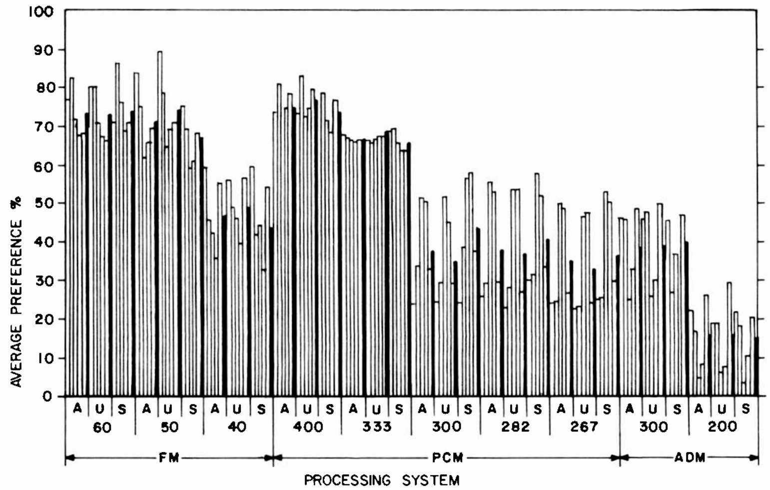


Fig. 4
Average selection preference (dark bars) showed best-quality FM and PCM essentially equal in paired-comparison tests. However, individual selections (white bars, numbered from left of each group of five) received varying preferences with different processing systems. On horizontal axis, *A*, *U*, and *S* are for "all," "unskilled," and "skilled" listeners; numbers for FM are *S/N* in dB; numbers for PCM and ADM are sampling rates in kb/s.

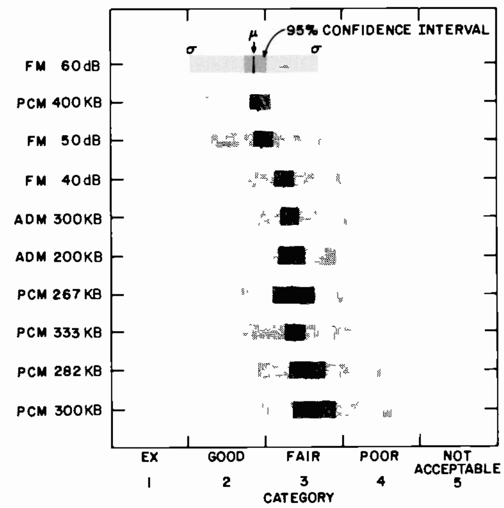


Fig. 5
Preference ranking by category judgment shows no significant difference among 60-dB FM, 50-dB FM, and 400 kb/s PCM, but ranks ADM higher than paired-comparison tests (Fig. 4).

quality of audio over the different kinds of transmission links. An estimate of the relative efficiency of digital and analog systems can be made by considering a 15-kHz music signal. If we assume that for digital transmission an intrinsic bandwidth equal to the bit rate is a practical, realizable value, then a system with coherent phase detection is capable of providing a bit error rate (BER) of about 10^{-6} with a carrier-to-noise ratio of 12 dB. The subjective evaluation shows that a 400-kb/s PCM signal produces a baseband signal that is subjectively equivalent to an FM system with a 50-dB *S/N* program level or, because music has a 13-dB peaking factor, a peak *S/N* of 63 dB. The digital signal could be transmitted in a bandwidth of 400 kHz at a *C/N* of 12 dB. If a lower BER is required, it can be achieved using error-correcting code techniques, which will require some additional bits.

Assuming a Carson bandwidth of 400 kHz for an FM signal, the modulation index for the 15-kHz baseband channel is about 12. Although this may not be the most efficient design for an FM system, it does allow the two systems to be compared in a common transmission bandwidth. At a modulation index of 12, a *C/N* of 25 dB would provide a peak *S/N* of 63 dB in the baseband signal. Assuming an improvement of 13 dB *S/N* through using pre-emphasis, the FM system using a 400-kHz transmission bandwidth would require a *C/N* of 12 dB, which is identical to the digital system.

The comparison made here is quite crude. There are many trade-offs of power and bandwidth possible for these two basic systems. The PCM signal was a linear signal without companding. One of the limitations of the PDP-11/20 system was its lack of digital storage; hence the need to truncate to 12 bits. The low levels, near 60 dB down, had minimum steps of several dB. It is conceivable that processing 14 or 16 bits per sample with companding to 12 bits or less per sample would provide a better-quality signal.

The results of this work show that digital processing of music can be achieved with a high degree of listener acceptance. At the present state of the art, analog systems probably have a slight edge over the digital systems reported here. If serious interest develops in satellite networking of high-fidelity music, more research into digital processing systems should be encouraged. In particular, work on better companding algorithms is desirable. The companding procedures reported here were really shallow, in that only variations of logarithmic functions were tried by table look-up.

The conclusions are clear. For many applications, digital systems can provide customer-acceptable monaural music of a given quality at essentially the same power level and bandwidth required by an FM system.

Acknowledgment

The advantages of a large integrated research laboratory such as RCA Laboratories are appreciated when one attempts a task covering several disciplines. The resources of these laboratories were used extensively in this work. We appreciate the leadership and interest provided by K.H. Powers and W.D. Houghton of the Communciations Research Laboartory. We also wish to thank all of the people who volunteered their time to listen to 90 minutes of repeated playings of the same five musical excerpts. Special appreciation is expressed to several individuals whose help greatly expedited the progress of the work: to W.G. McGuffin for circuit hardware development; to H.E. White for aid in interfacing the digital circuitry to the PDP-11/20 computer; to S.B. Calo for developing software for the processor; to J.J. Mezrich for consultation during the design of the tests and computer analyis of the paired-comparison data matrices; to L. Schiff and J.J. Gibson for discussions on system aspects of the three processing systems; to L.L. Stetz for aid in obtaining objective measurements and preparation of test tapes; to E. Cattani of RCA Records for providing the music source tapes and Dolby noise-reduction equipment; and to S.L. Roberts for recruiting and scheduling listeners, and also typing the manuscript.

Reprint RE-23-3-10
Final manuscript received February 4, 1977.

- Keeping abreast of the new technology in my field is quite important to my job performance.

- It is also quite important to my future career goals.

- My management places only moderate emphasis on the importance of my staying up-to-date.

- Technical information bearing directly on my job is the most important type of information I need, and having efficient access to it is extremely important to me.

- I obtain most of my job and career information through reading and through informal discussion.

- The five most useful information sources for me are (in order) my own files, engineers in my work group, books, handbooks and manuals, and engineers at my location outside my work group.

- I get most of my technical information about RCA from discussion with associates and from the *RCA Engineer*.

- I get much of my nontechnical information about RCA from the grapevine, from *RCA Trend*, and from my supervisor. I think other sources ought to be more productive so I would have to rely less on the grapevine.

- I spend eleven hours per week reading material that is relevant to my job and career. More than half of that reading is technical information, and more than half is done on my own time.

- The greatest obstacle I have to adequate reading is TIME. There isn't enough, either at work or outside.

Engineering Information Survey results

H.K. Jenny | W.J. Underwood

These are some typical responses from more than 50% of the engineers who completed the Engineering Information Survey described in the accompanying box. This article, which is the first of a series, analyzes the responses to the following questions:

How important is keeping abreast of new technology?

How important is efficient access to various types of information?

What information sources are used and what is their value?

How many hours do engineers spend reading various types of material?

To what extent are engineers staying up-to-date?

Engineers and their supervisors work in fields of constantly changing technology. For many, this changing technology has the following characteristics: its rate of change is high, its complexity is increasing, and its volume is expanding. Technology is changing from tangible to intangible, visible to invisible, concrete to abstract, manual to automatic. Information concerning new technology proliferates at a similarly high rate. The number of technical journals has doubled every 15 years since 1700. In 1970, some 3500 technical books were published. Books in science increased by 55% during the 50s and by 117% during the 60s. In chemistry about 250,000 books, articles, and papers are published each year. Patents have doubled every decade since World War II, and filing rates have reached 3000 a day.

How has living in the above milieu affected the attitudes and opinions of RCA engineers and their supervisors? How important do they think it is to keep up with the changes? The first three items on the Engineering Information Survey sought answers to these questions.

In these questions, *engineers* refers to all professional, technical, nonsupervisory employees working in the physical sciences. It includes those working in research, in design and development, and in manufacturing. *Supervisor* refers to all levels of supervision of the engineers, *leader* refers to the first level of supervision, and *manager* refers to all higher levels.

How important in your present job is keeping abreast of new technology in your field?

Importance	*Engineers*	*Leaders*	*Managers*
Extremely	32%	39%	40%
Quite	44	42	43
Somewhat	18	15	15
Slightly	5	3	2
Not at all	1	1	0

More than three-fourths of each occupational group rated keeping up-to-date in the two highest degrees of importance. It is interesting to note that supervisors assign new technology a higher degree of importance for their jobs than do engineers.

That practically all respondents (99%) would assign some *job* importance to keeping up with technology is probably not surprising. The importance it would have for their future careers was somewhat less predictable.

Reprint RE-23-3-20
Final manuscript received September 29, 1977.

Thanks for taking that half hour

During the first half of 1977, engineers and their supervisors throughout RCA responded to a questionnaire concerning the sources that supply information needed in their jobs and careers. This Engineering Information Survey was developed by the Technical Information Programs unit of Corporate Engineering. The purpose of the survey was to determine engineers' information needs for use in shaping programs aimed at satisfying these needs.

The questionnaire was completed by over 3000 individuals, about 75% of RCA's engineers. Returns were sufficiently balanced across such parameters as location, division, discipline, age, type of work, and job level to truly represent the RCA engineering population.

The major results of the survey will be reported in a series of articles in the *RCA Engineer*. These articles will present corporate-wide data. Additional reports will be made to local management, which will review location- and division-level results.

The staff of Corporate Engineering expresses sincere gratitude to all who responded to and administered the questionnaire. Completing a detailed questionnaire can interfere with business and personal pressures. The outstanding cooperation of RCA engineers resulted in an unusually high return rate and therefore credible data.

How important to your future career goals is keeping abreast of new technology?

Importance	*Engineers*	*Leaders*	*Managers*
Extremely	37%	38%	28%
Quite	47	47	52
Somewhat	14	12	18
Slightly	2	3	2
Not at all	1	1	0

Combining the two highest degrees of importance, engineers and leaders regard keeping up-to-date as more important to their futures than to their present jobs. Managers assign it only slightly less importance to their future compared with their present jobs, but concur that is is quite important.

Given that the respondents at all three organizational levels consider keeping up with new technology to be very important, how much emphasis on it do they experience from their management?

How much emphasis does your management put on the importance of your staying abreast of new technology in your field?

Emphasis	*Engineers*	*Leaders*	*Managers*
Very strong	7%	7%	12%
Strong	21	27	28
Moderate	37	36	39
Minor	23	21	15
None	11	8	5

How important to your job is keeping up with technology?

Less than half the respondents in each occupational group perceive a strong management emphasis on keeping up-to-date—36% to 39% regard the emphasis as moderate. The emphasis is felt strongest by managers, less by leaders, and least by engineers. Apparently upper management emphasizes keeping up with new technology, but the urgency atrophies as it passes downward through the organization.

The above responses clearly show that keeping abreast of technological change is regarded as quite important by engineers and their supervisors for the sake of both their present and future jobs. Middle managers seem to place importance on keeping updated but may not act to emphasize that importance to their subordinates.

Keeping abreast of technology, or anything else, requires having access to relevant information. The major purpose of the Engineering Information Survey was to explore access to needed information, not only technical information, but other categories that also seem relevant to job and career. Five categories of information were predefined in the survey:

- Technical—related to one's immediate job
- Technical—other
- Business—related to RCA
- Business—related industry
- Professional—the professional field of engineering

Respondents were asked to indicate the importance of access to each.

How important to you is having efficient access to the various categories of information?

The alternatives were: *Extremely, Quite, Somewhat, Slight, Not.* The percentages responding *Extremely* and *Quite* combined are as follows:

(%) Engineers	*(%) Leaders*	*(%) Managers*
95 Technical—Job	94 Technical—Job	91 Technical—Job
75 Technical—Other	75 Technical—Other	71 Business—RCA
41 Professional	55 Business—RCA	67 Technical—Other
36 Business—RCA	41 Professional	54 Business—Other
28 Business—Other	40 Business—Other	39 Professional

All three groups ranked job-related technical information as most important. In fact, more than 50% of each group assigned that category the highest scale position— *Extremely Important.* It was the only category ranked in the same position by all groups. The professional category is more important to engineers, less to leaders, and least to managers. Conversely, business information about RCA was ranked highest by managers, lower by leaders, and lowest by engineers. These positionings seem logical, considering the responsibilities of each group. An interesting result is that more categories are important to a greater percentage of managers; more than 50% responded to four categories. Three categories drew more than 50% of leaders and only two did so among engineers.

We now examine the methods and sources for obtaining information. Again using the previous information categories (Technical—Job, Technical—Other, Business—RCA, Business—Other, Professional), the study asked:

For each category, what percentage of your information is received through:

Reading?
Discussions with other engineers?
Educational courses?
Business meetings?
Professional society activities?

The responses were highly similar among engineers, leaders, and managers, and therefore are shown consolidated. Numbers in the table are the average percentages of information received via each method.

Method	*Technical job*	*Technical other*	*Business RCA*	*Business other*	*Professional*
Reading	40%	48%	41%	55%	51%
Discussions	34	25	36	23	19
Courses	8	10	1	1	19
Meetings	8	5	13	6	4
Societies	4	5	1	3	8

Reading is clearly the primary method used, with informal discussions second. Together they account for 70% or more of the information acquired. Reading and discussions are inversely related across categories. Reading is most productive for information that is not immediately related to job and company (Business—Related Industries, Professional). Discussions are most productive for Technical—Job Related and RCA—Business information.

Business meetings are the largest of the three minor contributors with their greatest utility in RCA—Business information. Among occupational groups (data not shown) business meetings were substantially more productive for leaders and managers than for engineers. Conversely, educational courses were more productive for engineers than for leaders and managers.

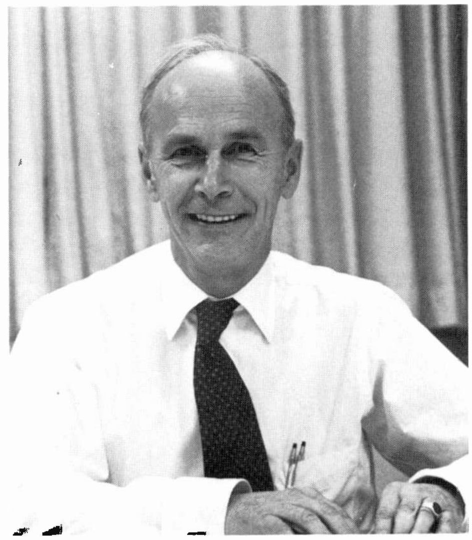
These five methods do not exhaust all possible methods for obtaining information. However, the totals of each column show that 88% or more of the information in these categories *is* obtained by the five methods listed.

Another question in the survey probed information sources in substantial detail. Thirty-two possible sources for obtaining needed information were listed. Respondents were given a four-point value scale (*Very Valuable, Moderately Valuable, Somewhat Valuable, Little or No Value).* They were asked to assign a value to each source. In the following table, the 32 sources are listed in rank order by the percentages of engineers assigning the top two scale positions (Very Valuable and Moderately Valuable). The table also shows the sources that leaders and managers ranked substantially differently from engineers.

How valuable to you is each of the following sources for obtaining useful information?

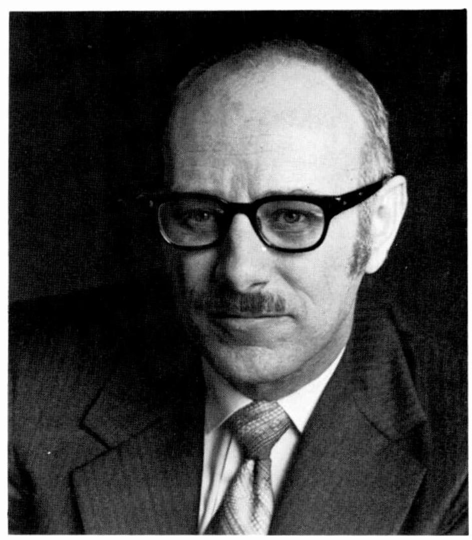
Engineers		*Leaders*		*Managers*	
%	*Source*	%	*Source*	%	*Source*
93	My own files				
87	Engrs. in my group				
78	Books				
76	Handbooks/manuals				
62	Engrs. at my location				
60	Data sheets/appl. notes			60	Internal meetings
58	Supervisors in my group				
56	RCA library			55	TRs and EMs
55	Catalogs			53	Supvrs at location
50	Standards handbooks			50	External meetings
46	Internal meetings	47	Ext. meetings		
45	Sales literature	45	Supvrs. at location	45	Data sheets/appl. notes
45	TRs and EMs			44	Engrs. at other locations
45	External journals				
41	External papers	39	Standards handbooks	40	Catalogs
38	External meetings	39	Sales literature	39	Standards handbooks
37	External courses			38	RCA papers
37	Internal courses				
35	RCA standards				
32	Engrs. at other locations	32	External courses	34	External courses
31	External libraries			32	Internal courses
31	Proceedings				
30	Military Specs. & Stds.				
29	Supvrs. at my location			29	External libraries
26	Professional societies				
25	RCA journals				
23	RCA papers				
22	External consultants				
14	RCA contract reports				
13	Supvrs at other locations				
11	External contract reports				
4	RCA editorial reps.				

Horizontal lines at the arbitrary 50% and 25% response levels divide the sources into three groupings that might be considered very important, moderately important, and slightly important, respectively. There is no doubt among these respondents that the engineers' own files and other engineers in their immediate groups are most



Hans Jenny has experience as a design engineer, engineering leader and manager, and Chief Engineer and Operations Manager of RCA's solid-state microwave product line. His present position of Manager, Technical Information Programs, uses this background to assist RCA engineers in their and the Corporation's efforts to remain viable and competitive.

Contact him at:
Technical Information Programs
Corporate Engineering
Cherry Hill, N.J.
Ext. PY-4251



Bill Underwood has a background that combines engineering and behavioral science. Since 1973 he has been associated with Corporate Engineering and is now the Director of Engineering Professional Programs. Previously, he was in Corporate Industrial Relations, specializing in management training and organizational development.

Contact him at:
Engineering Professional Programs
Corporate Engineering
Cherry Hill, N.J.
Ext. PY-4383

valuable. In fact, more than 50% of leaders, managers, and engineers assigned the highest scale value to their own files.

As noted previously, leaders and managers were in substantial agreement with engineers except where indicated. However, some of the sources differ systematically by occupational group. The value of external meetings and supervisors as information sources increases as organizational level increases. Conversely, standards handbooks vary inversely with organizational level as an information source. Also, educational courses, both internal and external, are valued more by engineers than by supervisors.

A prominent feature of the results (not revealed in the table data) is the distribution of response. For most sources, an appreciable number of responses existed at each scale position. In other words, deviation from the mean is large. The interpretation would seem to be that different people find useful information in different places. While some of the sources are highly valued by most, none can be considered to have insignificant value.

A number of sources were examined in regard to their value for supplying information about RCA. The first set concerned *technical* information and the second concerned *nontechnical* information. Regarding *technical* information about RCA, respondents were given a list of nine sources and were asked to indicate which they used and which were most important.

From which of the following sources do you get the major amount of technical information about RCA? Also, indicate which are most important.

	Engineers		*Leaders*		Managers	
	Use	*Import.*	*Use*	*Import.*	*Use*	*Import.*
Discussions with assoc.	1	1	1	1	1	1
RCA Engineer	2	2	2	3	2	3
RCA Trend	3	5	4	5	4	6
TRs & EMs	4	3	3	2	3	2
Discussions with super.	5	4	5	4	5	4
RCA educational courses	6	6.5	7	7	8	8
RCA seminars & lectures	7	6.5	6	6	6	5
RCA Review	8	8.5	9	9	9	9
RCA Tech. Abstracts	9	8.5	8	8	7	7

Numbers in the table are rank orders. Discussions with associates and the *RCA Engineer* were the first and second choices for each group in terms of use. *RCA Trend* and TRs and EMs were ranked third and fourth, but the order differs between engineers and supervisors. All groups assigned fifth position to discussions with supervisors. At least 50% of each group agreed with these five sources.

For engineers and leaders, the top five sources ranked by use were also considered the top five in importance. Managers agreed, except for elevating RCA seminars and lectures in place of *RCA Trend*.

To examine sources of *nontechnical* information about RCA, the survey presented thirteen sources and asked respondents:

From which of these sources do you get most of your nontechnical information about RCA? From which would you prefer to get it?

The primary obstacle to adequate reading for keeping up to date is lack of time.

	Engineers		*Leaders*		*Managers*	
	Use	*Prefer*	*Use*	*Prefer*	*Use*	*Prefer*
Grapevine	1	9	1.5	11	6	9.5
RCA Trend	2	3	3	3	3	3
Your supervisor	3	1	1.5	1	1	1
RCA Family News	4	5	5	4	4	4
Bulletin boards	5	4	7	5	10	8
RCA Communicate	6	6.5	6	6.5	5	5
Company meetings	7	2	4	2	2	2
Local newspapers	8.5	10	11	9	11	11
RCA Engineer	8.5	6.5	8	6.5	8	6
Electronic News	10	11	10	10	9	9.5
RCA annual report	11	8	9	8	7	7
Radio, tv	12	12	12	12	12	12.5
Community gossip	13	13	13	13	13	12.5

The grapevine is a primary source for engineers and leaders, but not for managers. Managers select their supervisors as the primary source and relegate the grapevine to sixth position. All groups place supervisors and *Trend* among the top three positions regarding use. *RCA Family News* is ranked in the top 5 by all groups. Three sources vary organizationally. Company meetings and the RCA annual report are used more by managers, less by leaders, and still less by engineers. Conversely, bulletin boards are useful in the reverse order. *RCA Communicate* is middle-ranked by all groups.

The occupational groups are in strong agreement on ranking these sources according to preference. All rank supervisors, company meetings, and *RCA Trend* first, second, and third, respectively. Interestingly, that is exactly the *use* ranking by managers. All agree that the grapevine should be a far less significant source.

Since reading was anticipated to be a widely used method for obtaining information, the survey inquired into the time respondents spend reading, and obstacles, if any, in doing so.

On the average, how much time during and after working hours in a typical week do you spend reading the various types of material listed below? Also, approximately how much of this total reading time is done during working hours?

	Engineers		*Leaders*		*Managers*	
	Total	*Work*	*Total*	*Work*	*Total*	*Work*
Technical—Job	5.0	3.3	6.0	3.6	6.4	3.6
Technical—Other	3.0	1.0	2.9	1.2	2.6	1.0
Business—RCA	0.9	0.6	2.0	1.4	3.3	2.4
Business—Other	1.1	0.3	1.6	0.6	1.9	1.0
Professional	1.5	0.9	1.4	0.5	1.9	0.5
Total	11.4	6.1	13.9	7.3	16.0	9.0
		53%		53%		56%

Numbers in the table are hours averaged across responses. Engineers average 11½ hours per week, leaders read about 2½ hours more than that, and managers average about 2 hours more than leaders. Engineers do a little over 50% of their reading during work hours; all three groups do more than 50% of their reading only for job-related technical and RCA business categories. Managers also do more than 50% of non-RCA business reading during work hours.

Job-related technical materials account for the largest allocation of reading time for all three groups. The second largest allocation of time is for non-job-related technical reading for engineers and leaders and RCA-related business for managers. Taken together, these first and second categories account for about two-thirds of reading time.

Eleven to sixteen hours per week is a substantial amount of time devoted to reading. Even the six to nine hours of reading during work represents 15% to 22% of a 40-hour work week. Apparently the claims of extreme proliferation of relevant printed material have merit.

Regarding obstacles, the survey asked:

Which, if any, of the following are obstacles to you in keeping abreast of new developments in technology by reading? Which are the one or two you consider most important?

Obstacle		*Importance*
69%	I do not have sufficient time to read at work.	48%
47	I do not have sufficient time to read outside of work.	24
27	I keep abreast by ways other than reading.	9
21	Management does not condone reading at work.	11
13	I need a better grasp of mathematics.	6
9	I need a better grasp of science.	5
4	I lack interest in reading.	2
3	Reading wouldn't help in my job.	2

The primary obstacle to adequate reading for keeping up to date is insufficient time, both at work and outside work. Twice as many engineers regard the insufficiency of time during work as more important than that outside work hours. A substantial percentage uses other methods than reading, which either diminishes the need for reading or competes with it for time. A slightly lower percentage feels constricted by management and regards this as the third most important obstacle. How many feel constricted by management is a function of organization level: engineers—23%, leaders—15%, managers—10%. Finally, some feel the need for a better grasp of math and science; the proportions who do are about the same in each occupational group.

After such a review of the importance of keeping up with technological change, the methods used, and sources of relevant information, it is important to see how engineers and their supervisors stand. How well are they able to remain technically viable as they see it?

How would you rate yourself in terms of being up to date with the current state of the art in your technical field? Answer with respect to other RCA engineers.

I'm in the:	*Engineers*	*Leaders*	*Managers*
Upper 10%	7%	26%	22%
Upper 25%	21	36	34
Average	37	31	36
Lower 25%	23	6	8
Lower 10%	11	0	1

Engineers are somewhat pessimistic—only 28% place themselves above average and 34% place themselves below average. This contrasts sharply with the allocations made by leaders and managers—62% of the leaders and 56% of the managers place themselves above average and only 6% and 9% locate themselves below. Of course, the question is relative and the responses are subjective. Still, it can be argued that engineers have a great deal of almost daily evidence with which to locate themselves in relation to their colleagues. The optimism of leaders and managers cannot be ascribed to a lack of importance of technology at their levels. Question 1 established that supervisors consider keeping up with new technology even more important than do engineers.

Concluding remarks

This survey has measured the need that engineers feel to keep up to date with rapid technological change. It has demonstrated some of the complexity, variety, and obstacles in doing so.

Technical obsolescence is insidious. There are very few mileposts to it along the way in an engineer's career, and those that do exist are blurred. Many technical people have awakened one day to the realization that they are behind, sometimes seriously so. Catching up is difficult because the target continues moving at a rapid pace.

The next paper in this series will show what is different about engineers who achieve more professionally than others. It will disclose what these "higher achievers" do to maintain their technical viability. It will demonstrate that the greater utilization of information sources is strongly related to solving the problem of falling behind.

Communication multiplexing

H.E. White

Communication capacity is being increased by multiplexing entire networks as well as individual circuits.

Today's massive communication networks use multiplexing to provide the economy of scale required to justify marine cables, microwave relay systems, and communication satellites. RCA interests in communication multiplexing range from concepts to system designs and include a number of services offered by our three common carriers—Globcom, Americom, and Alascom.

Ten years after the first trans-Atlantic cable became operational in 1868, it was duplexed to allow simultaneous transmissions in both directions.[1] While duplexing is a special case of multiplexing, it is motivated by the basic need to increase utilization of expensive communication circuits. Another early form of multiplexing was the simplex circuit, also known as the phantom circuit. As shown by Fig. 1, the simplex circuit rides piggy-back on two existing circuits, but is electrically isolated from them by the balanced transformer windings at each line termination.

While the early simplex circuits and duplexing increased effective communication capacity, they were not the answer to the spiraling demand for additional circuits. The first approach to large-scale multiplexing was space-division multiplexing, where many wire pairs are combined to form cables. These are laid between points requiring multiple circuits and are an important part of present-day communication networks. Space-division multiplexing also provides a basis of comparison for other forms of multiplexing, such as frequency-division and time-division multiplexing.

Recently, though, the effort has moved from circuit multiplexing to applying multiplexing to communication networks, especially since the advent of communication satellites and low-cost minicomputers and microprocessors. The very high cost of installing local circuits that connect subscribers to switching centers has also led to multiplexed subscriber loops that form local networks. After a brief review of basic multiplexing techniques, several examples of multiplexed communication networks will be given.

Multiplexing classes

The basic form of multiplexing is space division, which simply bundles many wire pairs into a common cable.

Installation costs and the cost of right-of-way are therefore shared among many circuits. A problem with space division, aside from the expense and bulk of the cable, is that coupling between circuits produces crosstalk between subscribers on separate circuits. Crosstalk can be minimized by wrapping cable conductors symmetrically and thus balancing out the crosstalk currents.

Frequency-division multiplexing, FDM, takes a number of incoming signals and translates them to non-overlapping frequency bands so they can be transmitted over a single wideband circuit.

FDM was originally thought of as an application of wireless techniques to metallic circuits. In 1910, Major George O. Squire of the Army Signal Corps noted that the same means of selective frequency generation and reception used for wireless transmission could also be used to increase the capacity of existing wire circuits.[2] Squire's patent, issued in 1911, is quite specific concerning the means for generating a plurality of ultrasound frequencies, modifying them by a telephone transmitter, and separating them by receiver circuits tuned to each of the transmitter frequencies. This is the basis for present-day FDM equipment, which simply translates incoming signals to non-overlapping frequency bands where they may be transmitted over a single wideband circuit. At the distant termination of the circuit, the signals are separated by filters and translated back to their original frequency bands.

Widespread application of frequency-division multiplexing required standard frequencies and frequency bands, which were specified by the FDM hierarchy used for long-haul transmission in the Bell Telephone System. As shown by Fig. 2, this defines the basic message channel (for voice communication) as 200 to 3400 Hz and specifies the basic group as 12 message channels with carrier frequencies in the 60-to-108-kHz range. The supergroup is defined as a combination of 5 basic groups, and other higher-order groups are also defined. All of the FDM groups are direct replacements for multipair cable, which would otherwise be needed in a space-division multiplex system. The FDM signal may, however, be carried by a single coaxial cable, a microwave relay system, or a satellite. None of these carriers would be economic for a single message channel, but

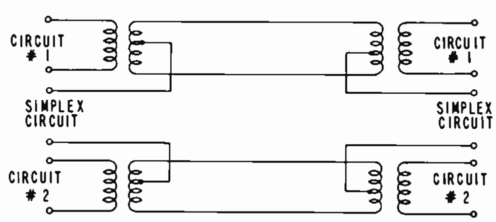


Fig. 1
Simplex circuit (middle), an early form of multiplexing, rides "piggy-back" on existing circuits, but is electrically isolated from them.

are readily justified when carrying a large FDM group of channels.

Time-division multiplexing (TDM) came into common use with the availability of high-speed switching transistors in the early 1960s.

Both the sampling theorem and pulse-code modulation (PCM) are closely related to the development of TDM. The sampling theorem specifies that a band-limited signal of bandwidth *B* can be exactly reproduced from samples taken at a rate of 2*B* or more samples per second. Pulse-code modulation provides a means of transmitting these samples as a string of binary pulses that may be regenerated many times as they are transmitted over circuits employing repeaters instead of amplifiers. While PCM is not an integral part of TDM, since analog signal samples can be time-division multiplexed, the development of TDM and PCM systems have proceeded together. Aside from their natural compatibility, this has happened because the Bell System called for PCM transmission over its TDM hierarchy. Like the FDM hierarchy mentioned earlier, the TDM hierarchy spells out the signal groupings that are used to share the available time of a wideband communication circuit. Fixed-time-slot TDM is represented in Fig. 3 by rotating commutators at each end of the circuit that sequentially connect a number of signal sources and sinks.

The first level of the TDM hierarchy is known as T1 carrier. As shown by Fig. 4, T1 operates at a pulse rate of 1.544 megabits per second to transmit 24 voice channels, each sampled 8000 times per second, in an 8-bit PCM format. Actually only 7 bits are used for signal information, with the remaining bit used for supervisory functions, so there are 2^7 or 128 possible amplitude levels that may be transmitted. In widespread use since 1961, the T1 carrier is used to interconnnect telephone central offices from 10 to 25 miles apart. If digital repeaters are placed at one-mile intervals along the circuit, the T1 signal can be transmitted over a metallic circuit that would otherwise carry only a single message channel. The capacity of existing circuits can thus be expanded by 24 times for the expense of installing repeaters and terminal equipment. T1 carrier is also a building block for higher-order TDM groups, as illustrated by Fig. 4. These groups are needed to fully load expensive satellite and microwave transmission facilities in much the same way as the FDM equipment mentioned earlier.

Multiplexing applications

Many multiplexing systems rely on the intermittent nature of speech.

The above discussion of space-division, frequency-division and time-division multiplexing assumes a point-to-point configuration where many parallel message channels are required. A good example is a submarine cable, which is primarily space-division multiplexed, but each wire pair may also be frequency- or time-division multiplexed. RCA Global Communications, for example, provides its

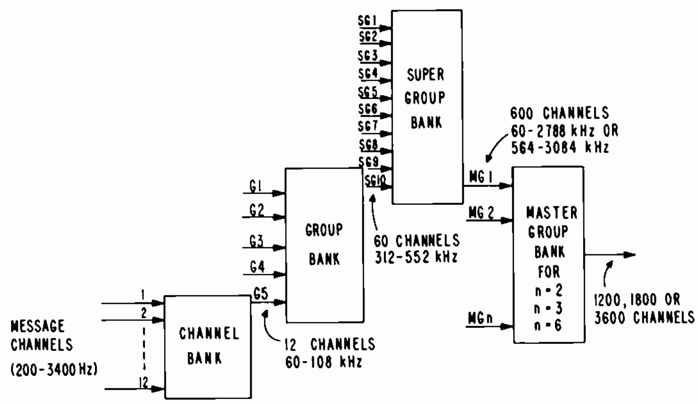


Fig. 2
Frequency-division multiplexing requires a standard hierarchy for combining message channels. Individual channels are grouped into channel, group, supergroup, and master groups for transmission on one channel. At receiving end, signals are separated by filters and put back in their original frequency bands.

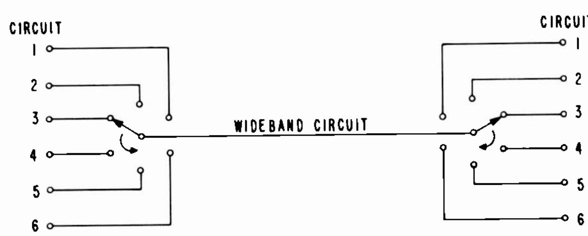


Fig. 3
Fixed-time-slot TDM uses rotating commutators at both ends of the circuit to sequentially connect a number of circuits over one channel.

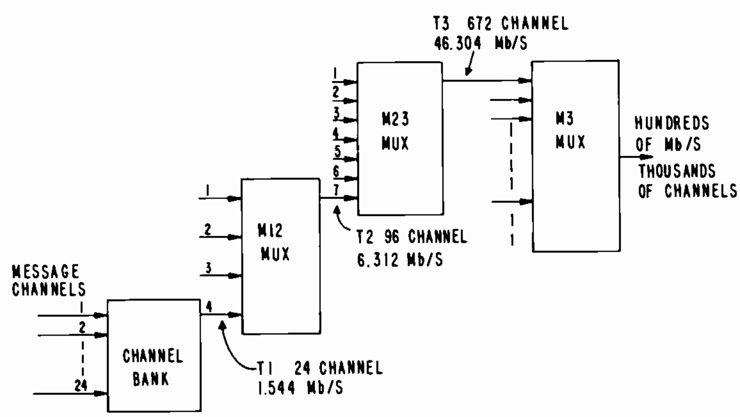


Fig. 4
Time-division multiplexing usually operates with digital pulse-code modulation, although analog TDM is possible. Scheme here starts with 24 voice channels sampled 8000 times per second, then goes through a number of higher-order groups to combine thousands of channels transmitted at megabit/s rates.

customers with a capability to frequency-division multiplex one voice channel and up to 5 teletype channels over a single leased circuit. Other more elaborate multiplexing schemes are also feasible over expensive cable facilities. One scheme uses the pauses occurring during a conversation to transmit high-speed data. Since each speaker should be listening at least half of the time, half of the channel capacity should be available for data transmission.

The intermittent nature of conversation was also used by the AT&T TASI[3] (Time Assignment Speech Interpolation) system. Here, another dimension was also used; namely, if many conversations are occurring concurrently, there is a high probability that almost half of the total circuit capacity is always available. The number of speakers can therefore be almost doubled if there is a means provided to share N channels among M speakers, where M is greater than N. While the control system needed to do this sharing on a statistical basis is not trivial, the original TASI system was constructed and tested on a trans-Atlantic cable before the availability of integrated circuits. A new all-digital version of TASI is now under test on microwave facilities between New York and Boston.[4]

The concept of sharing channels on a statistical basis has been further refined for data-communication applications.

Statistical time-division multiplexers that are an order of magnitude more efficient than older fixed-time-slot TDMs have been developed for data transmission. Input to these multiplexers is held in a queue until capacity is available on the transmission channel. The stored data from one or more users is then sent out as a block that includes addressing and error-control information. At the receiving terminal, a block is checked for errors, and, if errors are found, a retransmission is requested. Following correct reception, the data is distributed to the addressed users.

The extremely bursty nature of typical interactive computer data makes statistical TDMs very attractive. This was recently demonstrated by a system installed for RCA Laboratories, Princeton, N.J., to access the corporate computer center in Cherry Hill, N.J. A remote concentrator performs the data collection/distribution in Princeton; the complementary functions in Cherry Hill are provided by the front-end processor of the large time-shared computer. This system's ability to detect and correct transmission errors and automatically bypass faulty trunk circuits appears as important as its improvement in transmission efficiency.

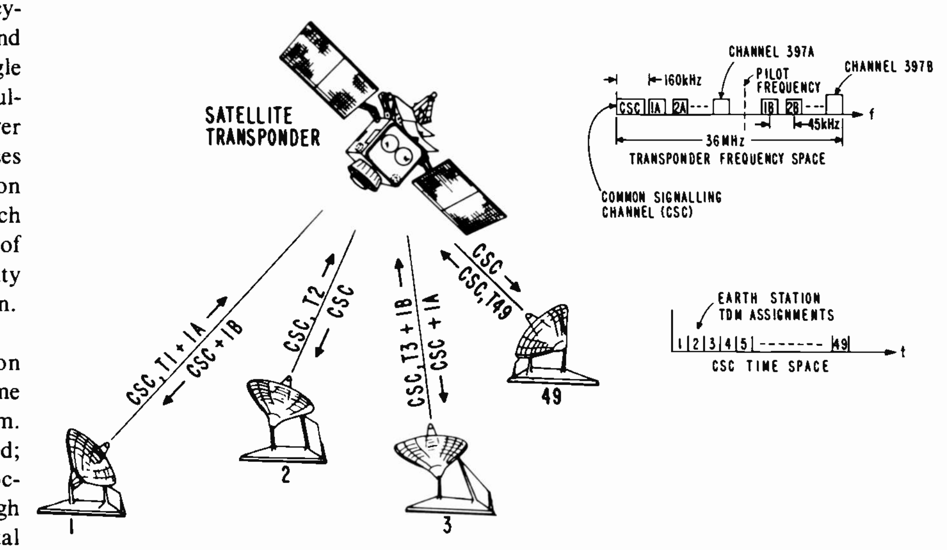


Fig. 5
SPADE multiplexing system interconnects many earth stations with satellite. Common signalling channel (CSC) keeps track of the rest of the message channels as the earth stations use them. In example shown here, earth stations 1 and 3 are communicating over channel 1. Earth station 1 then broadcasts its unavailability over the CSC and sends its message over channel 1A. Earth station 3 broadcasts its unavailability over the CSC and sends its message on channel 1B. All stations receive the CSC, but station 1 receives 3's message on channel 1B and 3 receives 1's message on 1A. After the message is completed, channel 1 is available for whatever earth stations want to use it.

Multiplexed networks

Statistical multiplexing's success in point-to-point circuits has led recently to applications with communication networks.

These include both national and international networks for voice and data and local networks for connecting subscriber locations to a switching center. The communication satellite has opened new opportunities for large-scale networks including the SPADE system[5] operated by Intelsat. With SPADE, a satellite's capacity is frequency-division multiplexed among many earth stations on a demand basis. One satellite message channel is used by a pair of earth stations to complete each incoming call. After a call is terminated, the same message channel can be used by another pair of earth stations to complete another incoming call. Fig. 5 illustrates the basic concepts of the SPADE system, showing how the available satellite frequency spectrum is divided into message channels and a common signaling channel. The signaling channel is used by all earth stations on a TDM basis to keep track of message-channel assignments. When an earth station seizes a message channel, this information is broadcast during that station's time slot on the common signaling channel. The other earth stations therefore remove that message channel from their list of available channels. In this way, channel assignments are coordinated without the need for a supervisory control center.

Packet switching is really an extension of statistical time-division multiplexing to a network.

Here messages, which are really streams of digital data, are broken into segments called packets at the originating node of the network. The packets are suitably addressed and then transmitted along the best available path to the destination node. The packets corresponding to a particular message may travel over different routes, depending on the current loading of circuits and nodes in the network. At each node, the packets are checked for errors, and retransmission is requested if errors are detected. At the destination node, the packets are assembled in their original order and delivered to the recipient.

A packet-switching network will automatically adapt to changing conditions within the network. This includes failures of trunks or nodes, which may be bypassed by alternate routing, as well as varying traffic loads from the many connected subscribers. The ability to average the traffic from many subscribers over many routes within the network allows high utilization of the network resources. This in turn allows usage-sensitive pricing, which is the key advantage of packet switching to many users. Present packet-switched networks base charges on the number of packets transmitted independent of distance. Simple transactions, such as querying or updating a data base, which were not economic when based on the cost of a three-minute phone call, thus become economic with packet switching. Packet switching is now being used in the ARPA net[6] and in commercial networks.

The advantages of packet switching will be extended to international data communications by the Datel II service to be offered by RCA Global Communications. The initially circuit-switched Datel II system will provide high-speed (4800 and 9600 b/s) data transmission on a demand basis. Later expansion will provide a choice of either circuit or packet switching and a complete range of synchronous and asynchronous data speeds to match any application.

The desire to reduce communication costs through multiplexed networks has reached the local distribution areas as well.

Subcriber-loop multiplex equipment has been available to Bell System and independent telephone companies for the past few years.[7] This equipment operates on a TDM loop network that is shared among subscribers connected to the loop. Such systems are particularly valuable in rural areas where the cost of installing and maintaining long local loops is high.

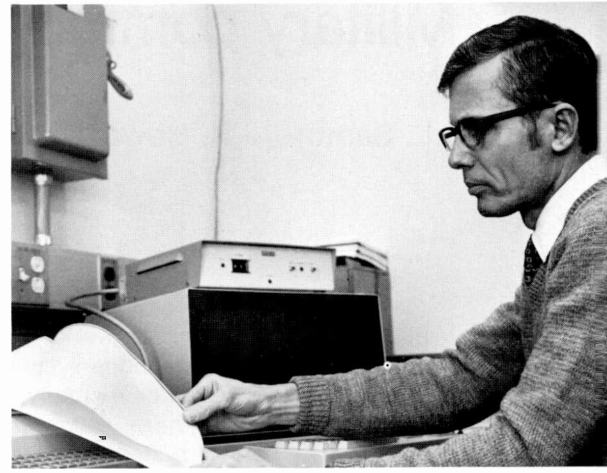
The principle of the TDM loop network is the basis for the Data Loop Exchange (DLX) System[8] used for internal data distribution at RCA Laboratories. In this case, the TDM loop network avoids the multiconductor cable and central data switch required by a space-division system. All subscribers are connected to the single twisted-pair loop network shown in Fig. 6. Since DLX divides the loop capacity into 32 TDM channels, up to 32 pairs of subscribers can communicate simultaneously. Actually, many more than 64 subscribers can be serviced by DLX because channel access is on a demand basis and inactive subscribers do not require loop capacity. In comparison to local telephone service normally used for data distribution, DLX provides higher data rates, lower error probabilities, and substantially lower costs. The cost advantage has become particularly evident because local telephone service is charged on a message-unit basis. The DLX system will be manufactured and marketed by an RCA licensee to customers with local data communication requirements.

Future trends

Advances in communication multiplexing will be related to the continued development of large-scale communication networks. These networks will permit resource sharing among many subscribers on a statistical basis and will include the latest computer and microprocessor-based technology. They will lower communication costs and thereby make new communication-related services economical, and these in turn will increase the demand for additional communications. This trend will require continuing innovations by communications suppliers; their ability to meet this demand will determine their competitive position in the marketplace.

Hugh White has been with the Communications Research Laboratory at RCA Laboratories since 1961. He was a member of the PANGLOSS project and contributed to the design and analysis of communications systems techniques for the Navy's Special Projects Office. He also worked on redundancy-reduction techniques for storing and transmitting image data. More recently he has worked on computer-to-computer data communications, including the design of an internal data network used at RCA Laboratories.

Contact him at:
Communications Research Laboratory
RCA Laboratories
Princeton, N.J.
Ext. 2168



References

1. Finn, Bernard S.; "Growing pains at the crossroads of the world; a submarine cable station in the 1870's," *Proc. of the IEEE*, Vol. 64, No. 9 (Sep 1976) pp. 1287-1292.
2. Squire, George O.; *Multiplex Telephony and Telegraphy*, Government Printing Office, Washington, 1919.
3. Fraser, J.M.; Bullock, D.B.; and Long, H.G.; "Overall characteristics of a TASI system," *Bell System Tech. J.*, Vol. 51 (Jul 1962), pp. 1439-1454.
4. Institute of Electrical and Electronic Engineers, *Spectrum*, Vol. 13, No. 8 (Aug 1976) p. 65.
5. Werth, A.M.; "SPADE: A PCM FDMA demand assignment system for satellite communications," *Conf. Record*, 1970 Int. Conf. on Communications, pp. 46-22.
6. Roberts, L. and Wessler, B.; "Computer network development to achieve resource sharing," *Proc. of SJCC*, Vol. 36, AFIPS Press, pp. 543-549.
7. Boxall, F.S.; "A digital carrier concentrator system with elastic traffic capacity," *Conf. Record*, 1974 Intl. Conf. on Communications, pp. 24B-1—24B-4.
8. White, H.E. and Maxemchuk, N.F.; "An experimental TDM data loop exchange," *Conf. Record*, 1974 Intl. Conf. on Communications , pp. 7A-1—7A-4.

Reprint RE-23-3-3
Final manuscript received March 30, 1977.

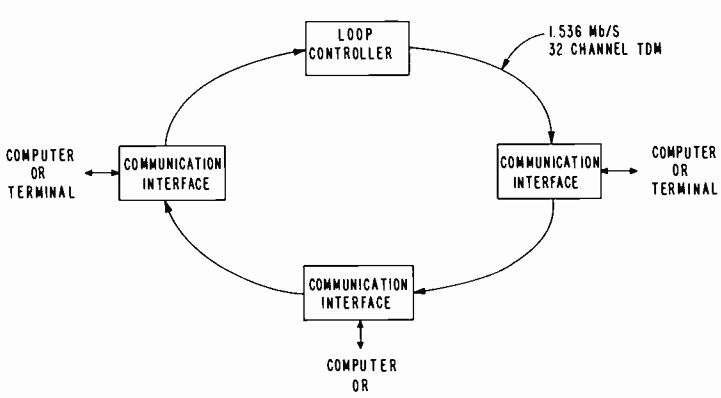


Fig. 6
Multiplexed local data loop is used for internal data exchange at RCA Laboratories. Alternative configuration would require separate cabling setups between all of the communicating locations.

Military communications — review and survey

J.L. Santoro | J.B. Howe

The trend is toward all-digital satellite links that provide better security, increased survivability, higher reliability, and more capacity.

Military communications networks range in type from standard voice-grade telephone systems to complex data links controlling missiles or remotely piloted vehicles via satellite. Collectively, these networks join our military command and control systems through a kind of global nervous system, delivering intelligence and surveillance information to the National Command Authority and control information to the forces.

Paradoxically, such communications are likely to be disrupted when most needed, since the elements of the system are widely dispersed, often on a global basis, and are thus difficult to defend. The continuing challenge is, therefore, to increase the survivability of the communications links to keep pace with developments in weapons and deployment of forces.

From the viewpoint of today's communication system designer, probably the most important tasks, beyond the continuing effort to improve reliability and data rates, are:

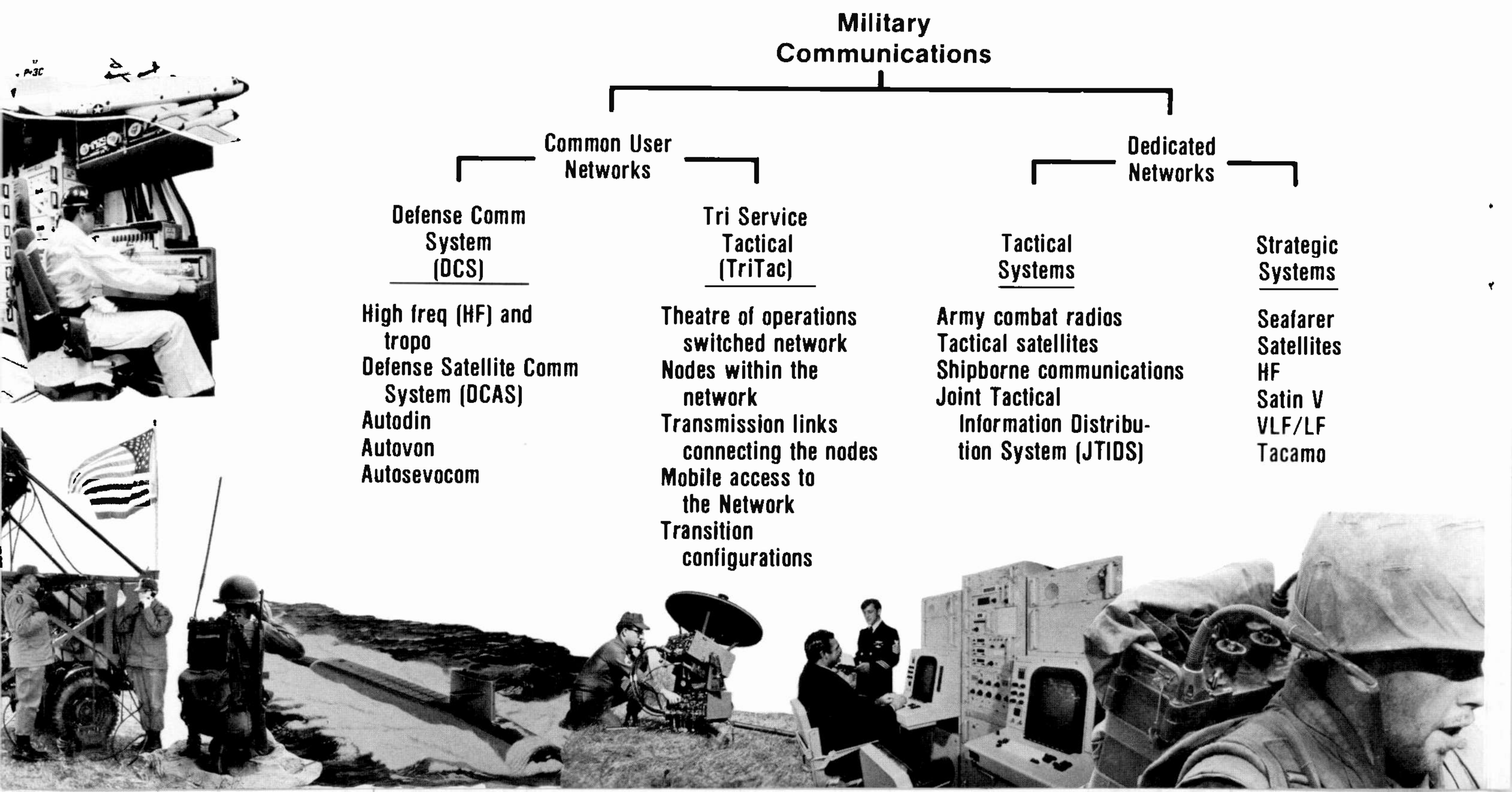
- increase hardening to avoid outages in a nuclear war.
- improve security to evade interdiction and spoofing.*
- add anti-jam capability to overcome electronic countermeasures.
- convert to all-digital transmission, which offers several inherent advantages—improved quality, increased security, and standard methods for handling voice and data.

This paper surveys the significant present and future military communications networks that have been, and are being, developed in response to these pressures.

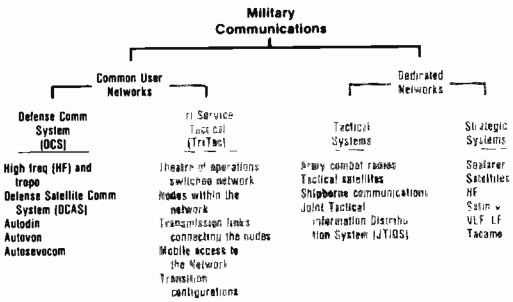
In general, any military communications system can be identified as either a common-user network or a dedicated network. Ideally, they should all be standardized, common-user types, but special strategic or tactical field requirements give rise to networks dedicated to a special function. (See Fig. 1.)

*In this context, *interdiction* means that an enemy could intercept and understand information in our communication system; *spoofing* means that an enemy could insert false information into our system and deceive us into thinking the information is valid.

Fig. 1
Basic military communications structure. The structure shown was chosen partly for this paper and partly because the networks have really emerged this way in response to global strategic and widespread tactical problems.



Common-User Defense Communications System (DCS)



DCS is the "in-place" worldwide system that serves as the foundation for emergency communications while concurrently satisfying normal peacetime needs.

The Defense Communications System (DCS) carries common-user traffic and extends command and control capability throughout the U.S., Europe, and the Pacific; the typical elements of the DCS network are shown in Fig. 2. The DCS uses practically every variety of transmission media, from cable to communication satellites. While 62% of these facilities are leased from commercial common carriers (e.g., AT&T, RCA, Western Union), the government-owned portion represents an investment of about $3 billion. The government owns and operates only a small part of the cable net used for DCS, but owns and operates a substantial number of radio links, especially overseas.

While the current network is based largely on the standard analog 4-kHz telephone channel, the move towards digital transmission is accelerating, for several reasons:

- Digital circuits are amenable to LSI technology, which generally results in lower-cost, more-reliable equipment.
- Digital transmissions can be secured by cryptographic techniques.
- Digital signals can be reconstituted at appropriate relay points providing better quality for long-haul transmissions.

Dependence on high frequency (hf) links is diminishing.

A number of hf links provide long-distance communications, carrying one voice channel or a modest number of teletype or low-speed data channels. Variations in the ionosphere cause relatively poor availability (95-99%) and unpredictable outages in even the best-engineered hf links with adequate frequency assignments. The fading characteristics of the medium, especially the selective fading resulting from multipath transmission, results in relatively high error rates on digital circuits. As a consequence, hf links are being phased out in favor of satellite systems wherever possible. In some cases, hf links will be retained as back-ups to other facilities to reduce vulnerability of the total transmission system.

Troposcatter and line-of-sight communications systems are also being replaced by satellite links.

The bulk of the non-satellite facilities in the government-owned portions of the DCS are multichannel radio-relay systems, either line-of-sight (LOS) operating in the 4- and 8-GHz frequency bands or tropospheric-scatter (tropo) links operating in the 1-, 2-, and 4-GHz frequency-bands. Most of the existing radio relays use frequency division mulitplex (FDM) to handle the standard analog channels. However, FDM is being replaced by digital transmission with new digital modems capable of data rates ranging from 24 kb/s, for what is termed narrowband, to multi Mb/s for wideband multichannel trunking.

While the military's reliance on line-of-sight and troposcatter channels is diminishing as DCS satellite capability increases, some of these facilities will be retained, as in the case of hf, for added survivability through redundancy. Also, line-of-sight microwave links will be used increasingly to connect users and the satellite earth stations. The military will probably also exploit the higher frequencies (above 10 GHz).

Defense Satellite Communications System (DSCS) use is increasing.

The DSCS continues to be a major customer for satellite channels from commercial carriers, and transmission over military-owned and operated facilities has been increasing dramatically. The first satellite for the Defense Satellite Communications System—Phase II (DSCS-II) was launched in 1971. Currently, two geostationary satellites, one over the Atlantic and the other over the Pacific, operating in the 7 to 8 GHz region, handle military traffic.

Reprint RE-23-3-6
Final manuscript received November 8, 1977.

Defense Communications Systems

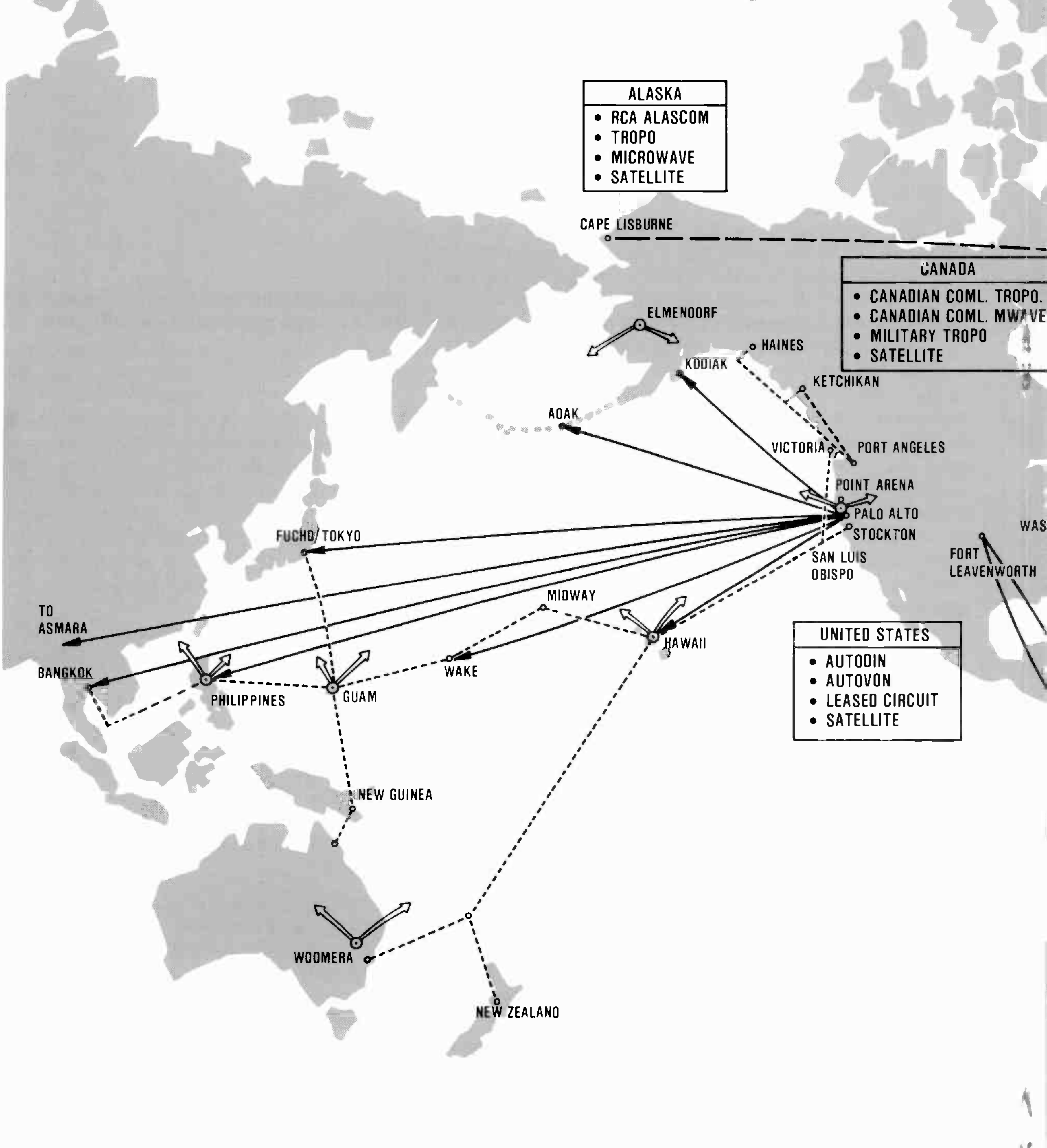
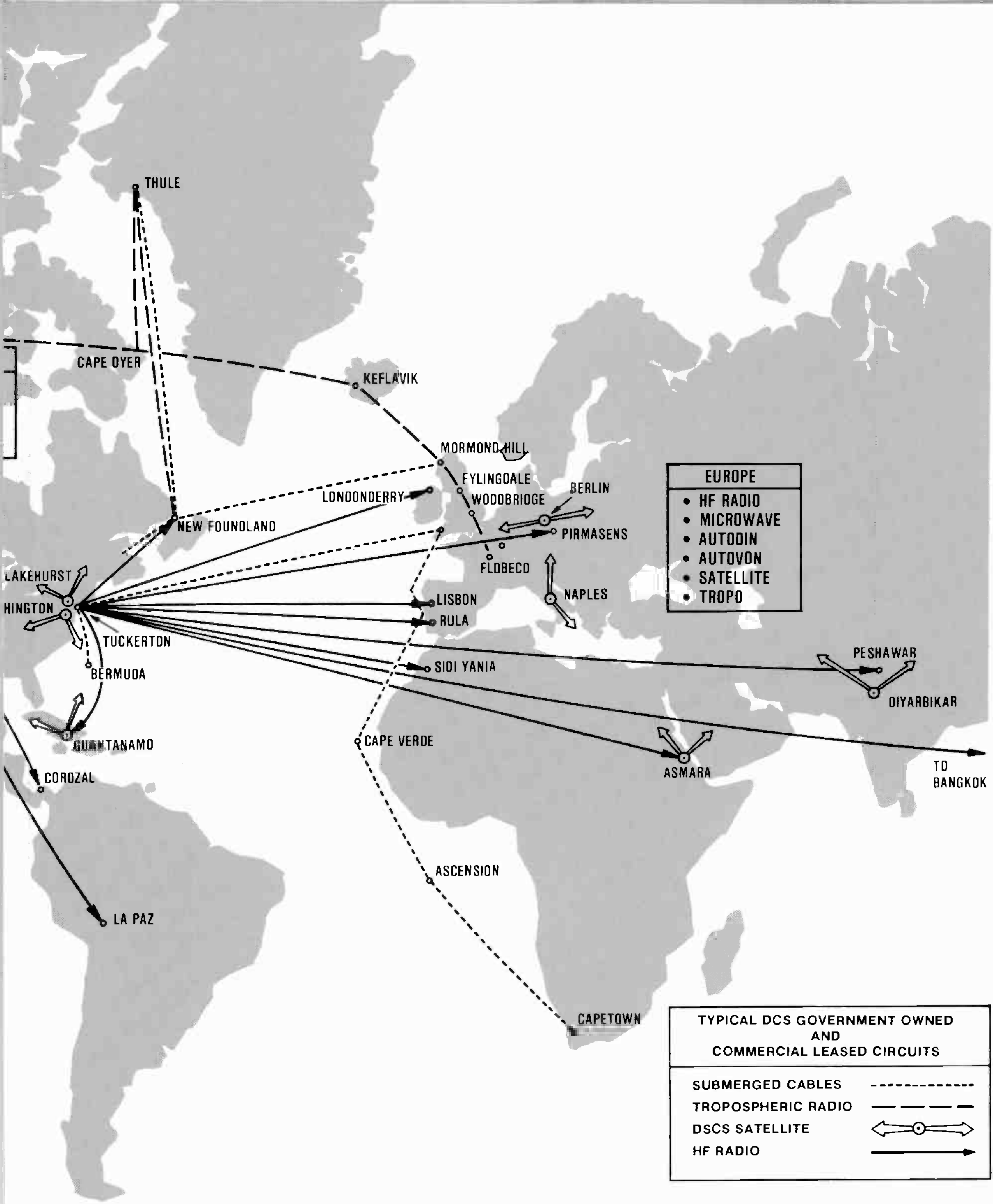


Fig. 2
Defense Communications System (DCS). This common-user system comprises about 42 million miles of various types of circuits (cable, satellite, microwave, etc.) that go to over 1000 locations in 70 different countries.

Earth stations of varying capability have been procured to provide service at 7 to 8 GHz. The larger terminals require carefully prepared large sites and are considered semipermanent installations. They are designed to handle large numbers of channels, are useful in safe areas, and need not be relocated often. To satisfy the needs of smaller, more vulnerable users, a family of truck-transportable terminals has been developed. These terminals are mounted in shelters for 1½ ton or 2½ ton truck transport. Each terminal is self contained and can provide full communications capability less than one hour after arrival at its site.* RCA has a contract for initial production of several terminal configurations for different channel capabilities. Other fixed, shipborne, and airborne stations are also being considered by the military.

*This program was described in Volume 22, No. 1 of the *RCA Engineer* by Tyree, et al, in "Small shf satellite ground terminal developments."



The government has recently started development of DSCS-III to further improve communications for command and control of our military forces. DSCS-III will carry six transponders, and its designers are considering the use of two independent multibeam downlink antennas, with patterns variable from 3.5° to full earth coverage. Existing ground terminals will be used. While DSCS-III is primarily for extension of current capabilities, the influence of digital traffic on military systems will likely cause a trend to time-division multiple-access (TDMA), and demand-assigned multiple access (DAMA) techniques to further increase system flexibility and capacity. Other changes, which include new special-purpose modems, can be expected to decrease the vulnerability of the satellites to jamming.

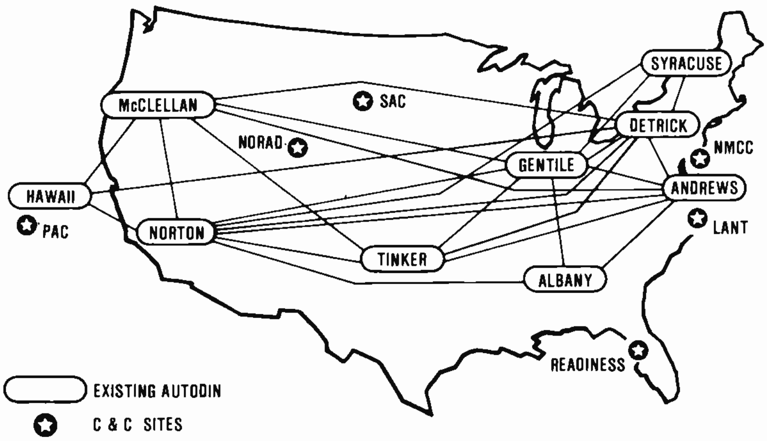


Fig. 3
AUTODIN is the DCS common-user data communication network for the continental U.S. and Hawaii.

Within the DCS, AUTODIN is the common-user data-communications system for the continental U.S. and overseas DOD subscribers.

AUTODIN is a message-switching store-and-forward service with nine switching centers in the U.S. and Hawaii and six centers overseas. (See Fig. 3.) In the U.S., Western Union is the system manager, and RCA supplied the switching equipment. A typical AUTODIN switching center includes controls, modems, and switches. The centers are connected, for the most part, by leased cable and microwave facilities.

The primary function of the AUTODIN I system is to deliver data messages from any terminal to any other terminal in the network. The system normally operates on a first-in, first-out basis but allows high-priority messages to take precedence.

The system handles about 600,000 messages (averaging 2000 characters/message) per day. Approximately 1400 terminals use the switches, with approximately 1150 in the Continental U.S./Hawaii areas, and the remainder in various international locations. Most traffic is narrative or record, which in general is message-structured, and does not require high-speed response.

Packet switching will be used on AUTODIN II.

AUTODIN II is a new development to accommodate the high speed response requirements of interactive subscribers, where terminal and computer response times may be much faster than AUTODIN I. This system will accommodate computer data-base transfers, as well as record traffic.

The approach is to send packets of data constituting either a small part of a message or the total transaction, as distinct from AUTODIN I where an entire message is collected before being routed through the network. Therefore, packet traffic of small transactions can be routed as soon as accepted by the originating packet switch as a burst transmission. AUTODIN I traffic will eventually be phased into AUTODIN II.

AUTOVON is the common-user telephone network that constitutes the backbone voice network for the DCS.

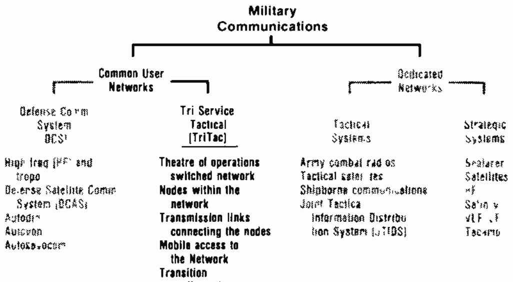
AUTOVON contains fifty-nine automatic switches in the U.S. and Canada, twelve automatic switches overseas, and has approximately 300,000 subscribers. It offers basically standard analog telephone service or priority service for command-control subscribers. In the U.S., the switching centers are connected by leased facilities with the inherent redundancy of the AT&T networks providing automatic alternate routing. The overseas DCS-owned environment results in a thinner connectivity.

In addition to the basic voice service, AUTOVON transmission facilities often act as backbone trunks for the DCS data circuits on a patched basis.

The AUTOSEVOCOM system provides secure voice channels for higher priority users located both in the U.S. and overseas.

The AUTOSEVOCOM (automatic secure voice communications) system presently consists of several automatic and manual switchboards to provide secure voice links for approximately 14,000 users. It can use existing trunking facilities to handle narrowband digitized voice (2.4 kb/s and 9.6 kb/s). It also provides high-quality wideband digitized voice (50 kb/s) over satellite and limited terrestrial trunking connecting local enclaves. The AUTOSEVOCOM system is predominantly a government-owned and -operated network.

Plans are now underway to upgrade the system in what is commonly called AUTOSEVOCOM, Phase II. This system will provide a more widespread capacity for digital secure voice channels with better quality for the 2.4 kb/s users and will standardize on 16 kb/s for the wideband users. The present concept is to use upgraded telephone company switches in the U.S. and the newly developed TTC-39 circuit switch for the overseas network. A new digital-access exchange switch is being developed to service local subscribers and act as the junction point to access the main trunking network.



Common-user Tri-service Tactical (Tri-Tac) communications

The Army, Air Force, and Navy have individual and collective responsibilities for defending national security. These "tactical" responsibilities cover a number of potential

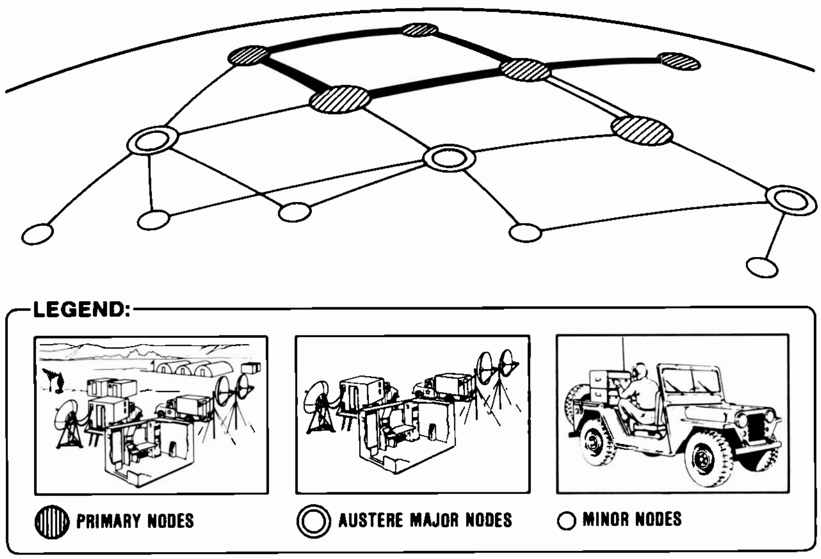


Fig. 4
Typical connectivity model for common-user tri-service tactical communications network. The composite network will service both area and command and control communications. Primary nodes serve the theater of operations headquarters. Austere major nodes and minor nodes are located closer to the battle area.

scenarios ranging from a "show of force" in the Middle East to large-scale combat as in Vietnam and Korea. For land operations, tactical Army and Air Force elements are generally assigned to a joint task force or theater-of-operations. For amphibious assaults, Marine Corps ground and air elements are assigned to an integrated marine amphibious force.

Looking to 1985 and beyond, "common-user" communications equipments for these types of tactical missions will be provided under the Tri-Tac program. The following paragraphs discuss the individual and collective roles of various tactical communications systems covered under the Tri-Tac program.

The theater-of-operations switched network has its primary node at headquarters.

The joint theater-of-operations network is organized as shown in Fig. 4. Major theater headquarters is serviced by the primary node, while tactical units closer to the battle area are serviced by the austere major nodes and minor nodes. The nodes can be located at the base or in the field, depending upon the tactical situation.

Each node in the network provides trunking connections and also serves as the network access point for both switched and dedicated user circuits. The concept illustrated in Fig. 4 projects a mature system in which radio communications also includes satellite terminals. The backbone of each major node is the 300- to 600-line AN/TTC-39 circuit and message switch presently under development. The austere major nodes will use a smaller switch, the AN/TTC-42, providing 75 to 100 lines. Tactical units (minor nodes) will use a 30- to 90-line switch, the SB-3865, for local and access switching.

Superimposed on this theater-of-operations switched network is the Tactical Communications Control Facility (TCCF), which is set up to handle system planning, system control, individual node control, equipment support, and satellite communications control.

Tri-Tac plans for post-1985 satellite communications are based on use of demand-assigned time-division multiple access (DA-TDMA) techniques.

Satellites are inherently limited in the number of simultaneous voice channels (or equivalent data channels) that can be transmitted. Current operation is limited by control and switching technology to dedicated channel assignments. Each network terminal is assigned a fixed number of channels based on the estimated traffic requirements limited by the total satellite capacity. Individual terminals may, therefore, instantaneously require more channels than they have been assigned while other terminals are using less than assigned.

Demand-assigned operation allows, through a control/assignment technique, the assignment of individual channels to each terminal as required. This arrangement requires a control terminal to have knowledge of the current status of all channels and to be able to assign an unused channel upon request to a network terminal. Such an operational approach allows the network to make maximum use of the satellite channels based upon the instantaneous channel requirements of the individual network terminals.

In the Tri-Tac plan, a primary master terminal will be designated to control system access while other terminals are designated as alternate masters. The active "master" terminal will generate frame-synchronization reference bursts; generate and distribute special network control and status information; and monitor and report subsystem performance. The DA-TDMA satellite communications system, however, will not depend entirely on the master terminal station; each terminal will have an internal processor that will perform all critical functions in real-time, independent of the monitor center.

The nodes will be connected by shf satellite communications; single and multihop LOS relay in the vhf, uhf, and shf bands; and single and multihop troposcatter at shf.

The terminals used in the demand-assigned (DA-TDMA) satellite system can generally be located within the nodal perimeters since they do not have the siting constraints of terrestrial-link terminals. Such terminals will be self contained; i.e., they will include all call-processing, preemption routing, and control functions required to set up demand-assigned channels between satellite terminals in cooperation with the associated Tri-Tac switching facilities.

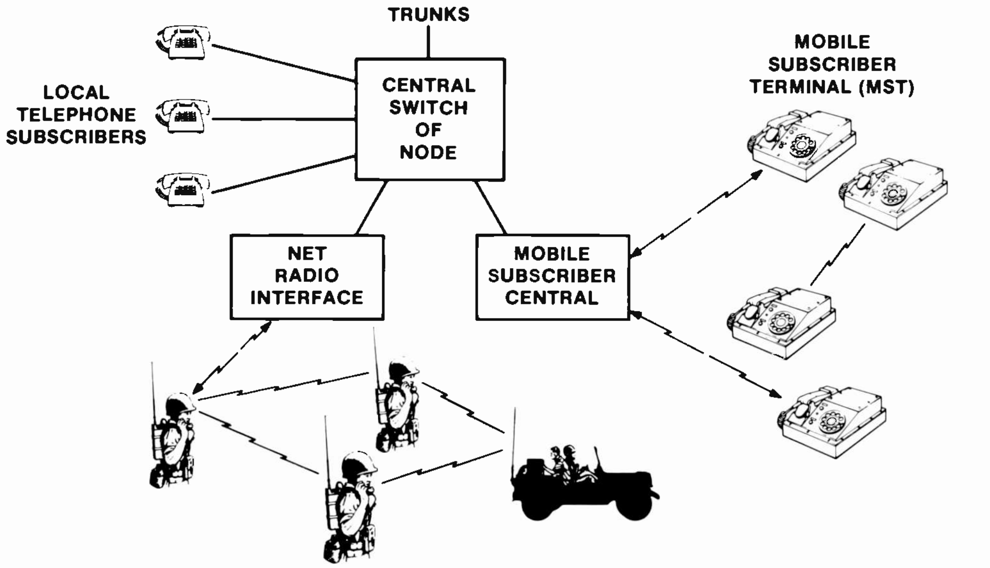


Fig. 5
Mobile subscriber access subsystem. A mobile subscriber can use the Mobile Subscriber Terminal (MST) to communicate directly with fixed or mobile units.

Thus, the satellite subsystem will appear to be transparent to the switching subsystem and, except for satellite-link propagation delays, will impose no unique constraints on other Tri-Tac system elements. In addition to the demand-assigned circuits, the satellite subsystem will be able to accommodate sole-user circuits of preassigned channels by establishing non-preemptable connections between terminal pairs.

The multichannel terrestrial radio terminals associated with a major node may be located 6 to 10 km from the node in an area designated the "radio park."

The Mobile Access Program will extend the tactical switched system to mobile telephone subscribers.

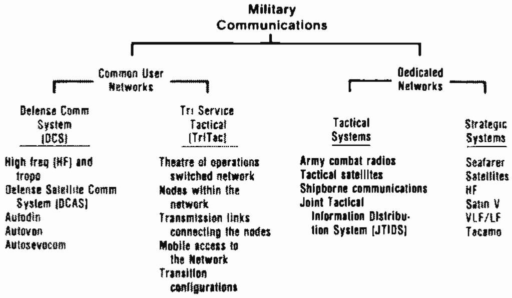
The Mobile Access Program integrates the functions of telephones, telephone switching, radio transmission, communications security, radio-wire integration, and control for mobile subscribers. This requires a family of mobile subscriber equipments arranged typically as shown in Fig. 5. A mobile subscriber equipped with a Mobile Subscriber Terminal (MST) can communicate directly with other fixed or mobile users on the network via the Mobile Subscriber Central. Radios of the SINCGARS variety (described later) will be capable of accessing the network via the Net Radio Interface.

As in DCS, the transition is to an all-digital system.

The preceding paragraphs have provided some insight into the architecture and equipments being developed for tactical communications systems under the Tri-Tac program. The transition from current tactical equipment inventories to the mature Tri-Tac posture will be evolutionary. While each service has its own plans for this transition, the following sequence will generally apply:

1) The initial systems deployed will consist of hybrid analog and digital switching equipments serving analog and digital subscriber terminals with wideband digital transmission links.

2) Later phases will approach (asymptotically) an all-digital system by phase-in of digital subscriber terminals and digital switching capacity and phase-out of analog terminals and switches.



Dedicated Tactical Systems

All military forces have the common problem of providing secure and reliable communications among mobile elements (ships, airplanes, ground vehicles, people) deployed in a given area of operations. The uhf band has been the most common for line-of-sight communications between aircraft and ground elements. For ground mobile elements, the Army has relied on vhf because of its better propagation characteristics in the types of terrain and antenna elevations unique to ground mobile communications. The Navy has relied on hf for non-line-of-sight fleet communications.

Generally, in the past, the military has survived without security or electronic counter-countermeasures in the

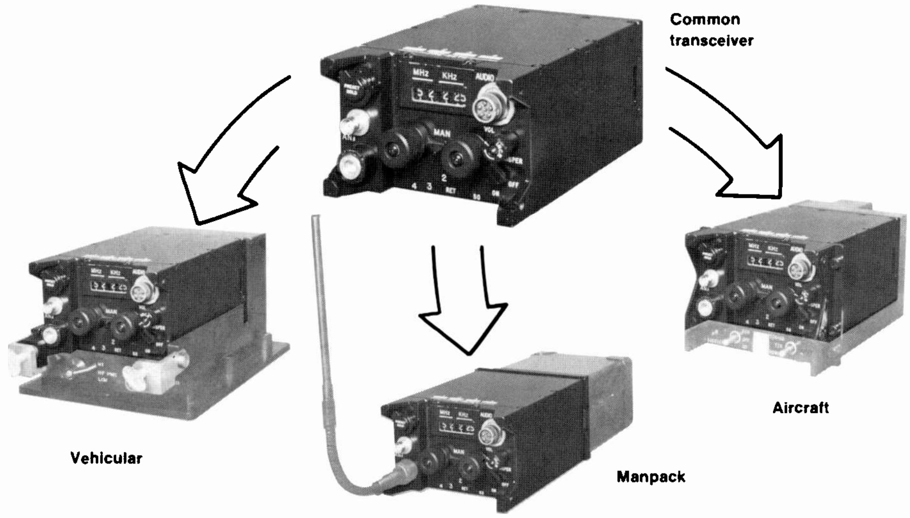
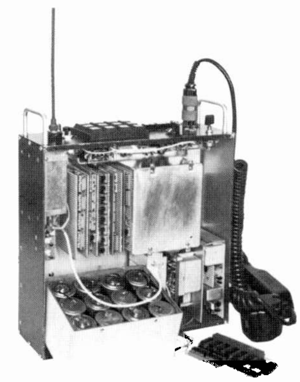


Fig. 6
This RCA-developed transceiver, the AN/URC-78, can be carried by foot-soldier or mounted in a jeep or aircraft.



RCA used the AN/URC-78 type modules to produce a manpack radio (above) that includes a capability for a frequency-hopping anti-jam mode.

tactical environment. However, recent experiences have demonstrated that more sophisticated measures are needed in the future. While these systems are classified as dedicated because of the specific environments in which they must operate, they are not totally divorced from problems of interoperability and must be built to interface with the Tri-Tac systems.

Some of the more advanced systems in operation today or under development to solve the problems inherent in the tactical arena are described in the following paragraphs.

Combat radios are becoming more important as combat becomes more mobile.

Warfare has become increasingly mobile; thus, command and control of the Army combat forces depends more and more on radio communications to replace the traditional wire-tie systems. Radios are carried by infantrymen, are mounted in military vehicles, and are carried aloft in the supporting Army aircraft. All these elements must communicate among themselves and with higher command authorities. For this mobile operation, the Armz primarily uses fm radios in the lower part of the vhf region (30 to 80 MHz). Some radios in the hf and uhf portions of the spectrum are also used for special applications.

In general, the combat radios are used to establish nets connecting each commander with his subordinate commands. The required range varies from one or two kilometers for the lower echelons up to forty kilometers or more for higher echelons.

More than ten years ago, the Army recognized the need to develop a new family of combat radios to

- improve spectrum use;
- enhance communications security;
- reduce vulnerability to enemy intercept, jamming, and deception;
- increase operating life; and
- ease logistic support.

To achieve these goals, the Army initiated a number of systems studies and advanced development programs. One of these programs produced the AN/URC-78, an RCA-developed transceiver about half the size and with longer life than the AN/PRC-77, the present standard radio. An important feature of this development is that the basic transceiver can be used as the central element in vehicular or airborne systems, as shown in Fig. 6. RCA subsequently used the AN/URC-78 type modules to develop and demonstrate a combat radio that included a frequency-hopping anti-jam mode.

The Army is now proceeding with the development of a Single Channel Ground Air Radio System (SINCGARS) at vhf, which is based on the results of these systems studies and advanced development programs.

Many of the communications requirements of the tactical users could be satisfied more effectively if they could take advantage of satellite communications.

The backbone multichannel transmission to and from field forces can be handled by shf satellites, analogously to the DCS. In fact, the small terminals described earlier are planned for use by the Army and Air Force. Other terminal equipments have been designed for large naval vessels. However, the size and cost of such terminals exclude many users at the present time who need such a capability. These users are typically small, mobile, and numerous, with a relatively small communications demand.

For such users, satellite communications must be at lower frequencies, where small, lower-cost equipment becomes practical. The military uhf band (225 to 400 MHz) was selected for this type of service. Initial experiments using the M.I.T. Lincoln Laboratory Experimental Satellites demonstrated the feasibility of uhf satellite communications for small mobile platforms, including aircraft, ships, and land vehicles. Later experiments under the joint-forces TacSatCom program, which incorporates both uhf and shf capabilities, also demonstrated this capability.

perspective

What is RCA's role?

RCA has been a major supplier of military communications equipment, systems, and studies virtually since RCA started manufacturing radio equipment in the early 1930s. Much of the work at Government Communications Systems is classified, and therefore cannot be mentioned here. However, the military communications systems listed below have all been developed by RCA, and provide some measure of our involvement.

HF Radios
AN/ARC-21
AN/ARC-65
AN/ARC-142
AN/ARC-161
AN/URC-88
AN/ARC-170
AN/ARC-185

Line-of-sight and troposcatter links
AN/GRC-50
AN/TRC-97
AN/TRC-97A

SHF satellite communications terminals
AN/TSC-85(V)2
AN/TSC-93
AN/TSC-94
AN/TSC-86( )

Strategic systems
Minuteman SCN
Sanguine
Integrated radio room (IR^2) for *Trident*

Switching systems
AUDODIN I
AUTOSEVOCOM
Integrated Circuit & Message Switch (ICMS)
Integrated Voice Communication System (IVCS)
Automatic Data Processing—Telecommunications (ADPT)

UHF radios
AN/ARC-34
AN/ARR-69
Time Division Data Link
AN/ARC-143
AN/ARC-143B (LOS & SatCom)

Army combat radios
AN/PRC-8, 9, 10
AN/PRC-25
AN/PRC-77
AN/URC-78

As a result of these experimental programs, the military has procured the FltSatCom satellite, which is scheduled for orbital operation in late 1977. This bird will carry repeaters for both the Navy Fleet Satellite Communications (FltSatCom) System and the Air Force Satellite Communications (AFSatCom) System. User terminal equipment for these systems has also been developed. The Navy is presently using uhf repeaters aboard the Maritime Satellite (MariSat) while waiting for FltSatCom to become operational.

The trends one may expect in this area in the future are similar to those for shf satellites:

- transition toward all-digital secure transmission;
- provision of antenna nulling and signal processing in the satellite to provide anti-jam capabilities; and
- demodulation and time-division multiple access and switching in the satellite to interconnect various uhf nets, uhf and shf users, broadcast transmissions, and conference calls.

With each new satellite system success, the demand for satellite channels will increase. The vulnerability of the satellite, however, both to jamming and to physical attack, will require that the other tactical communications modes be retained.

Shipborne communications are changing in response to tactical needs.

The Navy Tactical Data System (NTDS) was developed in response to the complex high-speed problems of directing a Naval task force in modern tactical combat. The system uses hf and uhf links to transfer important voice and data communications among ships in a task force via a polling scheme controlled by a master ship equipped with computers and displays.

The Common-User Digital Information Exchange Subsystem (CUDIXS) and the Submarine Satellite Information Exchange Subsystem (SSIXS) are link-control subsystems of the Navy's Fleet Satellite Communications (FltSatCom) program and are designed to speed the exchange of messages between ships at sea and shore-based stations. FltSatCom will afford more reliable communications over a much larger area than does the present hf system used by the Navy. The better quality (i.e., greater bandwidth, less "noisy") circuits provided can also permit signaling at a high transmission rate for the same or a lower error rate. A satellite channel can therefore permit one shore-based station to serve a large geographic area and, by time-sharing the use of the channel and signaling at a high rate, serve a much larger population of users.

New developments are underway to include anti-jam and low-probability-of-intercept capabilities.

The Joint Tactical Information Distribution System (JTIDS) is a secure information exchange.

Over the past 20 years, the military services have sought to develop a flexible jam-resistant secure digital information system to include location and identification information.

This effort culminated recently in the Joint Tactical Information Distribution System (JTIDS) program. The first phase of the program will be aimed simply at developing a system to distribute information in support of tactical missions. The second phase will include research and development to expand the information distribution capabilities and to add the location and identification functions to the system.

Basically, the JTIDS net serves as an information bus, where each user can select the specific information required for his part of the mission from the total. Thus, each user transmits important mission information to the bus, and receives only that portion of it required for his part of the mission. Some users may be largely information suppliers (e.g., forward air controllers, surveillance radars), others may be principally users (e.g., tactical aircraft, SAM sites), while still others (e.g., tactical air control centers) may both use and provide substantial information to the bus.

The basic element of JTIDS is a single secure time-division net, with time slots allocated among the users in accordance with their needs. The time-slot concept is illustrated in Fig. 7. The system is designed with all necessary control logic at the user terminal, allowing the net to be controlled from any station. Each time slot contains a synchronization burst, the transmitted information, and a guard period. The individual bursts employ spread-spectrum techniques and error-correction coding, to afford protection against jamming. JTIDS operates from 962 to 1215 MHz, a band currently occupied by the location and identification systems TACAN and IFF. However, the JTIDS signal design permits compatible operation with those other services. The range of the net can be extended beyond line-of-sight by aircraft relay, and the relay function can be assumed by any terminal.

The basic technology required to implement JTIDS exists, and rapid advances in solid state technology, in particular, make such a system feasible for many applications. However, there remains a significant challenge to drive the cost and size down to a sufficiently low level that more universal use becomes economically and operationally attractive.

Jack Santoro, as Manager of Systems Engineering, is responsible for military system development for Government Communications Systems.

Contact him at:
Systems Engineering
Government Communication Systems
Government Systems Division
Camden, N.J.
Ext. PC-3117

Joe Howe, as Chief Engineer for Government Communications Systems, directs RCA's design and development efforts on military communications equipment.

Contact him at:
Engineering
Government Communications Systems
Government Systems Division
Camden, N.J.
Ext. PC-2646

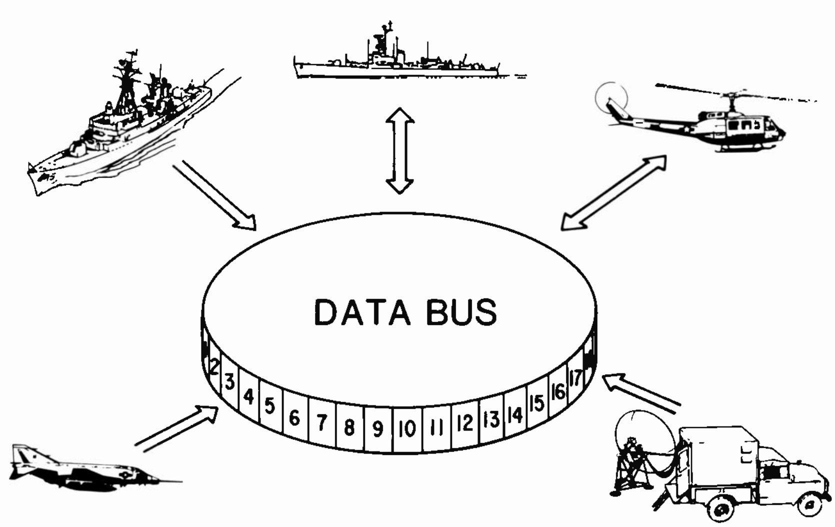


Fig. 7
JTIDS data bus concept. Timeslots are allocated to users based on need.

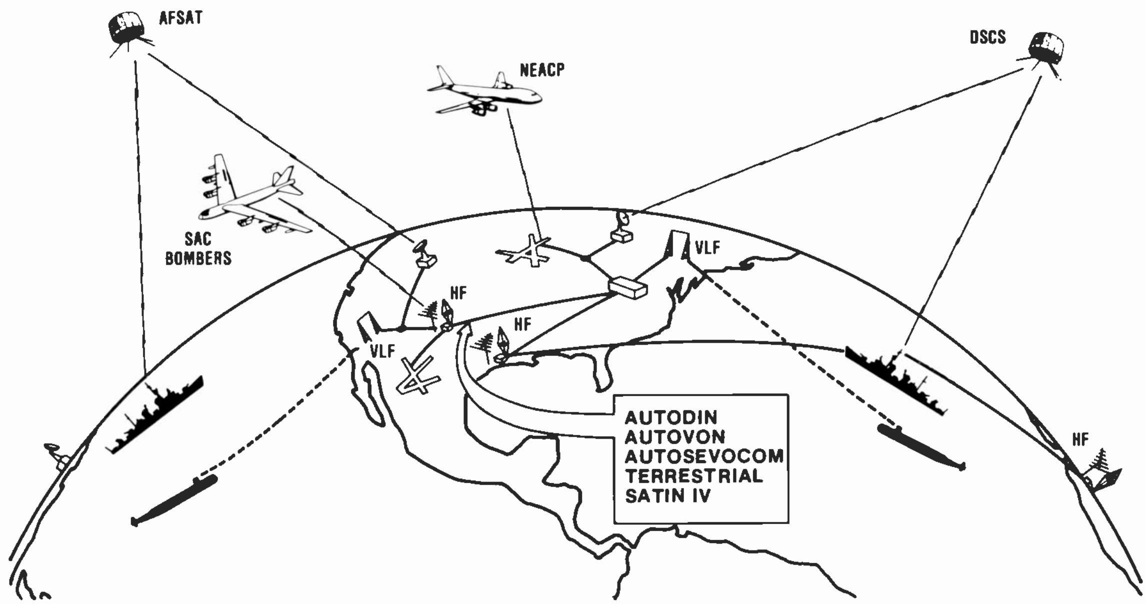
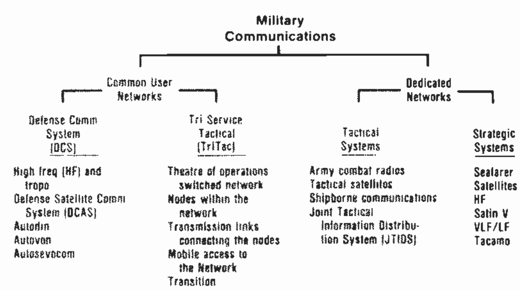


Fig. 9
Typical strategic communications network.



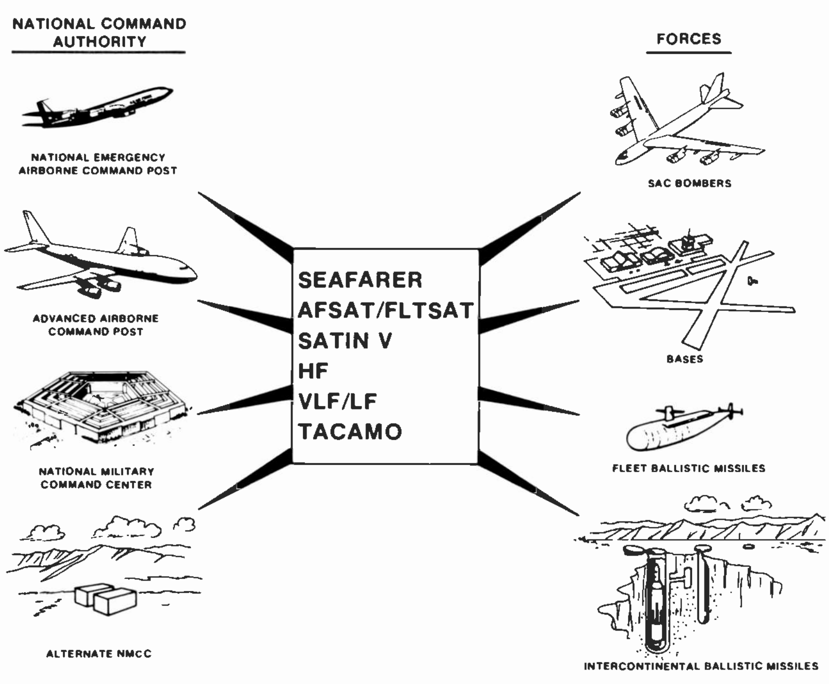


Fig. 8
These dedicated stratetic systems connect the National Command Authority with weapons systems and forces.

Dedicated strategic systems

Strategic networks assure communications between the National Command Authorities (NCA), the Joint Chiefs of Staff, and the commanders who need to execute integrated operational plans and other time sensitive operations. These systems allow the NCA to go directly to the forces as well as to the unified and specified commanders as shown in Fig. 8. A discussion of these dedicated stategic systems would be too lengthy for this paper, since they are so many and so varied. For completeness, however, several typical strategic systems are listed below:

- The National Emergency Airborne Command Post (NEACP) that can remain airborne over the U.S. for long periods of time, providing survivable communications with the other strategic networks.
- The Advanced Airborne Command Post (AABNCP) is an extension of NEACP using a 747 aircraft for expanded capability.

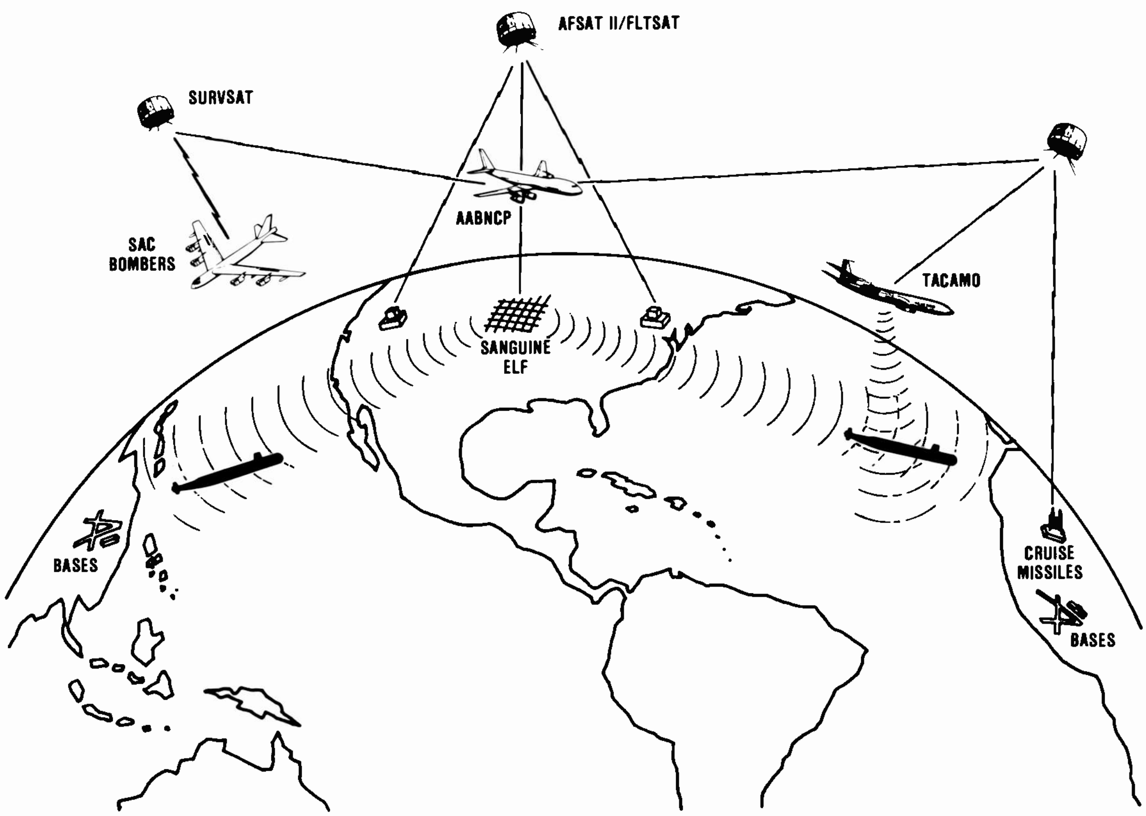


Fig. 10
For the future, the strategic communications network presents a changing picture, with primary emphasis on survivability.

- The Seafarer system (formerly Sanguine) that will provide (if implemented) survivable long range communications via extremely low frequency buried transmitters. The buried antennas will extend over large land areas.
- The Satin IV system for the Strategic Air Command (SAC) will be a totally automated data communications network linking SAC bases with each other and with missile sites.
- The very low frequency system, both ground based and airborne, will deliver messages to strategic elements on a global basis.
- Satellites and hf radio have obvious strategic applications.

The dedicated strategic systems will be interwoven into the AUTODIN, AUTOVON, and AUTOSEVOCOM types of common-user nets to use the redundant connectivity provided by them.

These dedicated systems are illustrated in Figs. 9 and 10 and are part of what is known as the World Wide Military Command and Control Systems (WWMCCS).

Concluding remarks

All-digital communications systems are the wave of the future. Three reasons are:

Cost: With the standard LSI packages proliferating, digital equipment becomes less expensive to buy and to maintain. Digital systems also have inherently more capacity per channel and thus are less expensive to operate.

Performance: Total link performance is independent of distance since digital signals can be regenerated as often as necessary; noise and distortion in an analog system are cumulative. Furthermore, digital systems can handle voice, facsimile, teletype, and computer data in a single transmission.

Security: This growing military need is more easily satisfied with a common digital standard.

For these reasons, the military communications users are replacing their analog systems with digital ones. The changeover is evolutionary. Thus, for a considerable period of time, older analog systems will coexist with digital ones. However, since operating in this transition is costly—more costly than all-digital or all-analog operation—we can expect the military to move to digital systems as fast as judiciously possible.

Survivability of our communications in the case of nuclear weapons effects or electronic countermeasures is becoming increasingly important. This is very costly to achieve, but new technology now available will allow more rapid growth in this area also. Again, it will be an evolutionary process.

Computer optimization produces a high-efficiency 4-GHz MESFET linear amplifier

F.N. Sechi | H.C. Huang

These amplifiers will probably replace TWTs in satellite communications.

Many communication systems rely on saturated microwave amplifiers for high output power and high efficiency, which are particularly beneficial in satellite communication systems. Yet, it is becoming clear that linear microwave amplification is desirable for satellite systems so they can operate with multiple carriers in a single rf channel. The high linearity of such a system generates a low intermodulation, or, in other words, a low interference between the carriers. Each carrier might be generated by a simple small earth station. Thus, many earth stations can access the transponder directly without a large multiplexing network on the ground and without a large earth station for wideband large-capacity transmission. This mode of operation is extremely attractive for interconnecting small stations situated in remote locations. For instance, Alaskan villages can be connected to a central communication network through inexpensive low-capacity ground stations.

The key element in this system is the power amplifier at the output stage of the transmitter in the satellite transponder. Until now, travelling wave tubes (TWTs) have been used for this application. However, to obtain a sufficiently low intermodulation distortion, powerful TWTs have been operated at an output power 10 to 15 dB below their maximum capabilities. As a result, their efficiencies are low (about 4%), which is detrimental in satellite systems. Thus, an amplifier featuring a high linearity together with a high efficiency is clearly needed. This paper shows that amplifiers using GaAs metal Schottky-barrier field-effect transistors (MESFETs) can meet this need.

A MESFET for replacing TWTs

Although our goal is to develop a 20-dB multistage amplifier, presently one of the power amplifiers has been developed and will be described here. It provides more than 300 mW of output power at 40 dB intermodulation distortion, with 13% efficiency and 12.5-dB gain from 3.7 to 4.2 GHz. This performance shows that we are one step closer to replacing TWT amplifiers in satellite transponders requiring linear power amplification.

The power MESFET we used has its GaAs pellet flip-chip mounted on a copper pedestal.[1,2] This ensures both a low parasitic source connection to ground and a good heatsink for the pellet. Gold ribbons connect gate and drain to the carrier, and tabs connect the 0.070-in.-long carrier to the circuit.

This type of MESFET features a gate length of approximately 1 μm with a total gate width of 3000 μm obtained by connecting 20 gates in parallel. When tested at saturation, these devices can deliver more than 1 W of output power at 4.2 GHz with a power-added efficiency of 37% and a small-signal gain of 13 dB.

Optimizing performance

For our application, the FETs had to be evaluated for intermodulation performance. While carrying out this evaluation, with the device mounted in a test fixture, it became clear that the rf output tuning for

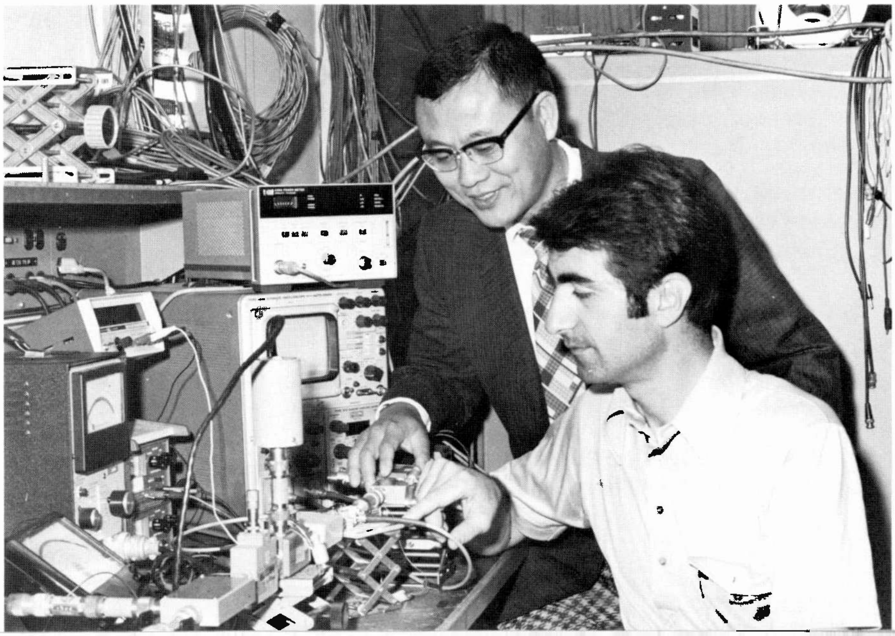
Ho-Chung Huang joined RCA in 1969 and has been heavily engaged in microwave fabrication technology, device physics, and circuit interaction since 1970. He initiated the GaAs Impatt program at RCA and proposed a high-low junction Impatt structure, now widely adopted, for the improvement of dc-to-rf conversion efficiency. He also directs the fabrication of GaAs MESFETs for high-power applications.

Contact him at:
Microwave Technology Center
RCA Laboratories
Princeton, N.J.
Ext. 3349

Franco Sechi designed solid-state microwave radio link equipment for ITT in Milan, Italy, before joining RCA Electronic Components as a design engineer in 1968. In this position he designed various types of transferred electron oscillators and developed a technique for measuring the impedance of transferred electron diodes under large-signal conditions. In 1973 he transferred to the Microwave Technology Center at RCA Laboratories, where he is presently developing high-power microwave transistor amplifiers.

Contact him at:
Microwave Technology Center
RCA Laboratories
Princeton, N.J.
Ext. 2529

Authors **Huang** (left) and **Sechi**.



lowest intermodulation differed from either the tuning for maximum saturated output power or the tuning for maximum gain; a systematic characterization of the active device was needed.

Device characterization was obtained with the aid of a computer-controlled tuner and a spectrum analyzer, both connected at the output of the device under test.

Fig. 1 is a simplified block diagram of the measurement set-up. The signals from two generators are amplified by power TWTs, combined, and fed to the input of the device under test through an input tuning circuit. The output of the device is connected to a load through the computer-controlled tuner, which consists of a coaxial slotted line with slugs riding on the center conductor.[3] These slugs, driven by stepping motors, can be positioned very accurately. The load impedance, Z_L, is then computed from the position of the slugs and is plotted directly on a Smith chart. The output power can also be read by the computer.

For the intermodulation measurement, two equal-amplitude carriers, separated by a few MHz, are fed at the input of the device. The output signal contains the two amplified carriers plus the unwanted intermodulation products. A spectrum analyzer measured the carrier-to-intermodulation ratio, or C/I ratio, in dB, between the amplitudes of the carrier and the highest intermodulation product.

The instrument was programmed to vary load impedance and search for either maximum output power or contours of constant output power.

Fig. 2 is an example of the results with the rf input power kept constant at 46 mW. The load impedance at the center of the circle-like contours provides the maximum output power, and each contour is the locus of the load impedances producing a constant output power. The contours are plotted at power steps of 0.3 dB. While the instrument was plotting each power contour, the C/I was measured on the spectrum analyzer and marked on the contour. Many contours, corresponding to different values of power, were traced, and a second set of contours, constant C/I lines, were derived by connecting points of equal intermodulation. This dependence of the intermodulation on load impedance derives from nonlinear phenomena in the active device. To a great extent, these phenomena, such as current saturation, voltage clipping, and

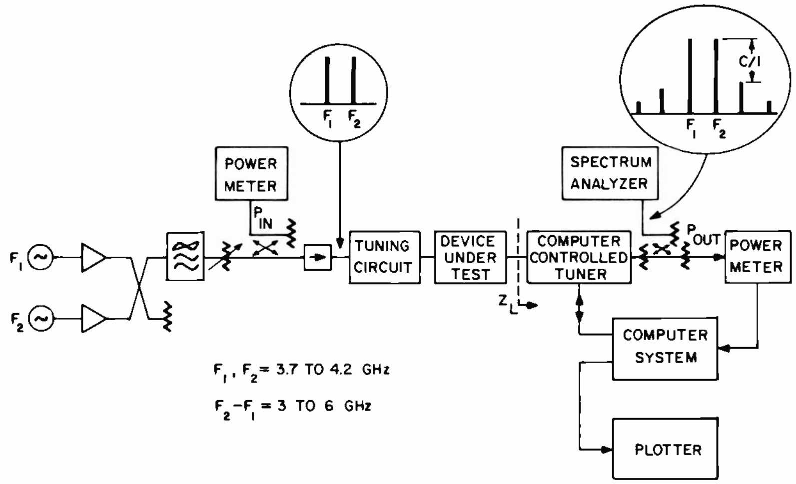


Fig. 1
Device characterization and optimization were done using this measurement set-up. Two signals are fed to the device under test through an input tuning circuit, and the device output is connected to a load through a computer-controlled tuner that searches for maximum or constant output power.

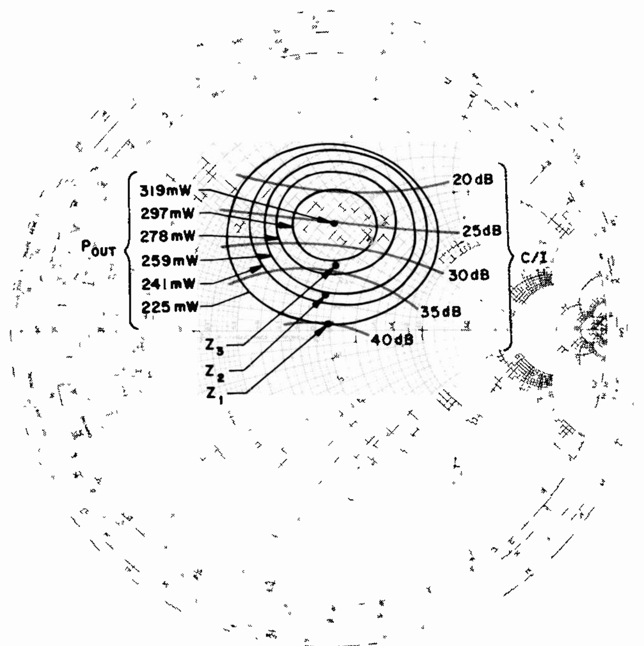


Fig. 2
Smith-chart output produces two sets of curves. The circle-like contours give the load impedances producing a constant output power, with the center point giving the maximum output power. The other set of contours gives load impedances having the same intermodulation. Optimum load impedance falls on a line orthogonal to both contours; the three Z values shown are on that line.

modulation of the average carrier velocity, are controlled by the output loading.

Although more than one value of load impedance can provide the same output power, i.e., 0.3 dB below the maximum value, the corresponding C/I values can differ by more than 12 dB. Note that these impedance contours are plotted with a reference impedance of 10 ohms. (In other words, the center of the chart is 10 Ω.) When referenced to 50 ohms, the true impedance of the test system, these data show, for instance, that the 12-dB variation in C/I can be caused by reflection-coefficient variation of only 15%. In other words, the intermodulation is very sensitive to the device's rf tuning.

This question then arose: how can one select the optimum load impedance from these data?

Certainly such impedance lies in the lower semi-plane, as load impedances falling in this region result in higher C/I ratios for the same output power. Also, for a constant C/I, the best load impedance is the one closest to the center of the power contours. Thus the optimum load impedance will fall on a line orthogonal to both the C/I and power contours. Since the rf input power is also a variable, similar measurements were performed at different values of input power to define the relationships between input power, output power, and intermodulation at fixed values of load impedance, for instance, Z_1, Z_2, and Z_3.

Fig. 3 plots output power vs C/I for the three different load impedances Z_1, Z_2, and Z_3, chosen in the optimal area for intermodulation performance. At a constant value of C/I, 40 dB for instance, Z_1 gives the highest output power, but the gain is lowest, while Z_3 gives lowest power but highest gain: the marked output powers were measured at constant input power. These are the data that a designer needs in order to choose the load impedance for the best compromise between output power, intermodulation, and gain. Moreover, one can predict the variation of the C/I for a variation of the input and output powers. These measurements, repeated at different frequencies, defined the optimum loading over the full operating bandwidth.

Amplifier design

The circuit design of the amplifier can be outlined as follows: the output circuit is computer-optimized first to present the FET with an impedance that closely follows the optimum load impedance for best output power and low intermodulation distortion over the operating bandwidth. Then the active device, characterized by its S parameters, is loaded by the optimized output circuit. Finally, the input circuit is computer-optimized for high and constant gain over the operating bandwidth. This procedure results in an amplifier having nearly optimum power and intermodulation distortion over the operating bandwidth while still maintaining, over the same bandwidth, high and constant gain.

The optimum load impedance for the device described varied from $10 + j\,0\ \Omega$ at 3.7 GHz to $10 + j2.5\ \Omega$ at 4.2 GHz. This small variation of reactance over frequency is attributed to the low-parasitic package.

The output circuit, a double $\lambda/4$ transformer, also was designed to follow the optimum load impedance closely over the operating bandwidth. The impedance plots show the excellent tracking between the two curves. The input impedance of this power FET is approximately 3 Ω. The input tuning circuit was designed as a double $\lambda/4$ impedance transformer preceded by a $\lambda/2$ resonator, which broadbands the tuning circuit so that a relatively good match can be achieved over the full bandwidth. Fig. 4 is a photograph of the amplifier.

Amplifier performance

The frequency response of the amplifier is described in Fig. 5. At 25 mW of input power, the output power is 410 to 490 mW over the operating bandwidth, with an associated gain of 12.1 to 12.9 dB. At 100 mW input power, the amplifier delivers more than 1 W with a power-added efficiency of 36 to 39%. Although the gain for this single-stage amplifier is high, there are no gain peaks at low drive that could lead to potential instability.

Fig. 6 and Table I give the intermodulation performance measured at the high side of the bandwidth with two equal-amplitude carriers 6 MHz apart. The output power, power-added efficiency, and input power are shown as functions of C/I. For instance, at an input power of 17 mW, C/I is 40 dB, with an output power of 300 mW and a power-added efficiency of 13.3%.

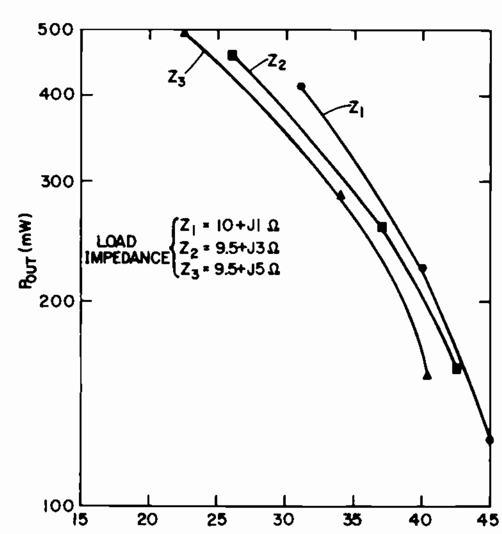
The output power and efficiency remain remarkably constant.

Over the operating bandwidth at an intermodulation of 40 dB, the power remains between 300 and 319 mW and the efficiency between 13.3 and 14%. Also, the gain of 12.2 to 12.9 dB is considered high for a single-stage broadband amplifier.

Efficiency is better than for TWTAs.

But perhaps the most important feature in this amplifier is the high efficiency at low intermodulation distortion. Although the efficiency of 13-14% at a C/I of 40 dB would drop to 9-10% for a multistage 60-dB-gain amplifier, that value is still far better than what is presently achievable with other amplifiers—a typical high-gain low-power FET amplifier, operating in the same frequency range, has an efficiency of 1.5% at a C/I of 40 dB. Bipolar amplifiers are slightly worse, and a double-collector TWTA has an efficiency of about 4%.

Fig. 7 shows the gain and the phase between the amplifier's input and output rf



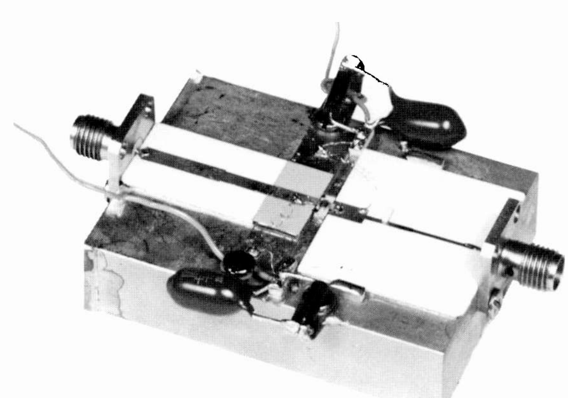


Fig. 3 (left)
Output power plotted against intermodulation for the three load impedances chosen from Fig. 2. Designer must use these curves to make the best compromise among output power, intermodulation, and gain.

Fig. 4 (above)
Linear amplifier has FET at center. Quarter-wave input transformer is built on 5-mil substrate; rest of circuit is built on 25-mil substrates. Output circuit, composed of two more quarter-wave transformers, is followed by 50-ohm line.

signal as functions of the input power and gate voltage. (These are single-carrier measurements.) Gain variations and phase distortions produce intermodulation distortion. For a peak envelope input power of 34 mW and a gate voltage of −2.34 V, there is a slight gain compression and a phase distortion of 2.5%. Under these conditions, the measured C/I was 40 dB. At a gate voltage of either 2 or 2.5 V, the intermodulation performance degraded by 5 dB. Since in this range of gate voltages the amplitude characteristic maintains the same shape and changes monotonically with the gate voltage, but the phase characteristic undergoes a significant change in shape, we can conclude that a change in phase distortion is responsible for the variation in intermodulation.

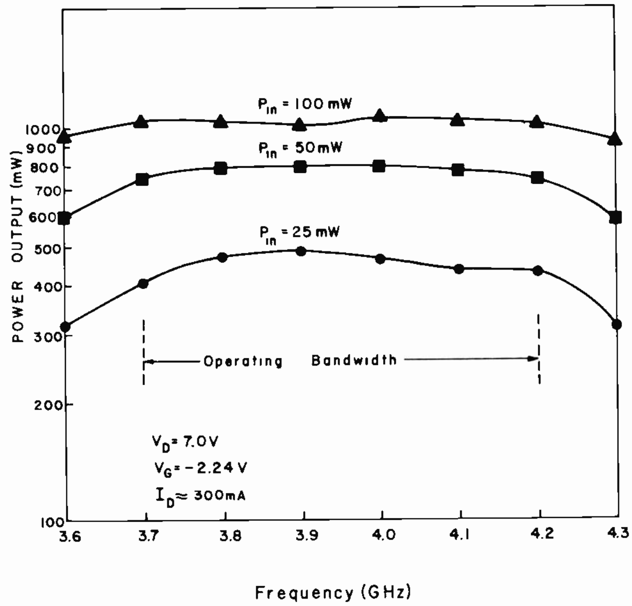


Fig. 5
Frequency response of amplifier shows no potential instability despite high gain.

Conclusion

The power amplifier described here is highly linear, highly efficient, and operates over a wide frequency band. Specifically, it provides more than 300 mW of output power over the 3.7-4.2 GHz range with a carrier-to-intermodulation ratio of 40 dB, an efficiency of 13-14%, and a gain of 12-13 dB. These values of efficiency are far above what is presently available either with solid-state or TWT amplifiers. The key factors in achieving this performance were the development of high-efficiency high-linearity MESFETs and the development of an amplifier design technique that is based on a device characterization for intermodulation performance. The resulting amplifier has nearly optimum power, intermodulation distortion, and gain over a broad bandwidth.

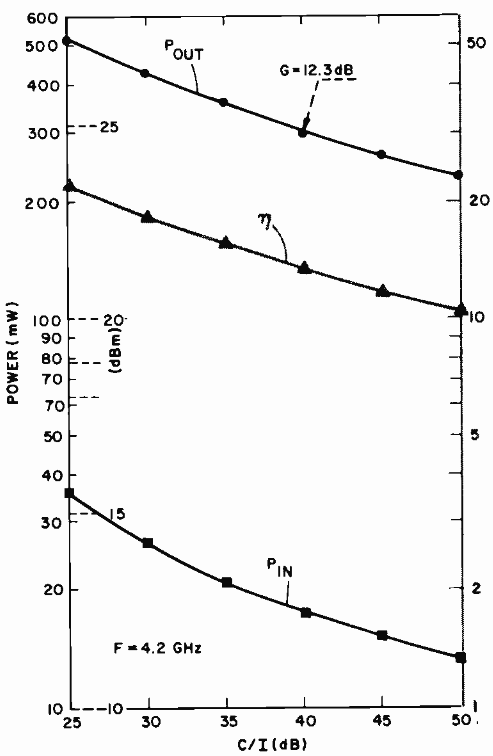
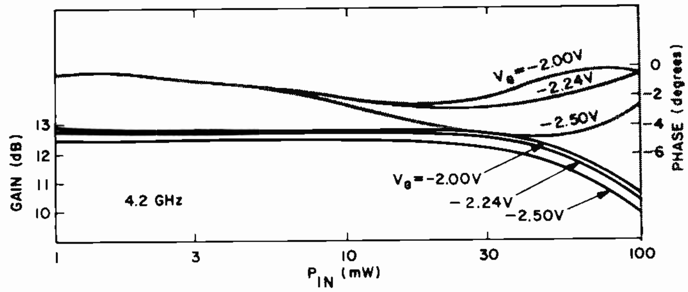


Table I
Output parameters remain constant over the entire 4-GHz band.

	Frequency (GHz) 3.7	3.95	4.2
P_{OUT} (mW)	304	319	300
η (%)	13.3	14.0	13.3
Gain (dB)	12.2	12.9	12.3

Fig. 6 (left)
Intermodulation performance measured at the high end of the bandwidth shows good efficiency and gain at 40-dB operating point.

Fig. 7 (below)
Intermodulation distortion is caused by change in phase distortion, as curves of gain and phase vs. input power and gate voltage show. Phase characteristics have 2.5-degree phase dip that produce 5-dB performance degradation; gain characteristics show no significant change in shape.



Acknowledgments

We thank L. Carr, W. Sked, and F. Wozniak for fabricating the MIC components, and E. Mykietyn, J. Brown, and A. San Paolo for assembling the MESFETs and circuits.

References

1. Huang, H.; Drukier, I.; Camisa, R.; Narayan, Y.; and Jolly, S.; "High efficiency GaAs MESFET amplifiers," *Electronics Lett.* Vol. 11, No. 21 (Oct 16, 1975).
2. Huang, H.; Drukier, I.; Camisa, R.; Jolly, S.; Goel, J.; and Narayan, Y.; "GaAs MESFET performance," *Digest* of International Electron Devices Meeting, Washington, D.C. (1975).
3. Perlman, B.; Sechi, F.; Paglione, R.; and Schroeder, W.; "An automated load-pull test system," *private communication.*

Reprint RE-23-3-7
A similar version of this paper was presented at the International Solid State Circuits Conf., Phila., Pa., in February 1977.

Receiver voting extends two-way-radio range

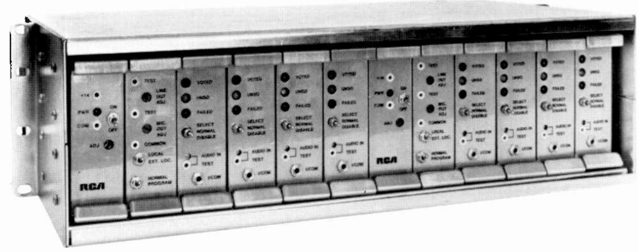
D.D. Harbert | R.G. Ferrie

Adding power increases the range of a portable radio, but it also increases weight and cost. Voting receivers extend range without these disadvantages.

Low-power personal, portable, and mobile radios generally have talk-back ranges much shorter than the talk-out range of their higher-powered base stations. Receiver voting is one method of remedying this situation—it electronically selects the best audio signal from two or more remotely located receivers that are receiving the same message. Land lines or microwave links connect the remotely located receivers to a central location, where the selection takes place.

RCA Mobile Communications Systems, in Meadow Lands, Pa., has developed such a voting system; in it, a signal-quality evaluator circuit for each receiver generates an output voltage indicative of the signal-to-noise ratio at its input. The signal-quality voltage of all the receivers is sampled periodically, and the best audio is "voted" and switched to the dispatcher. The selection is held until a S/N improvement of at least 2 dB in another receiver changes the vote.

The voting system is designed to operate with narrowband vhf and uhf fm radios. They operate on the land-mobile frequencies assigned to government agencies, such as police and fire departments, and industrial and public users, such as trucking and taxicab fleets.



Voting comparator equipment panel contains the modules necessary for a two-channel, four-receiver-per-channel voting system comparator station. Each channel requires a power supply, a control module, and a comparator module for each receiver.

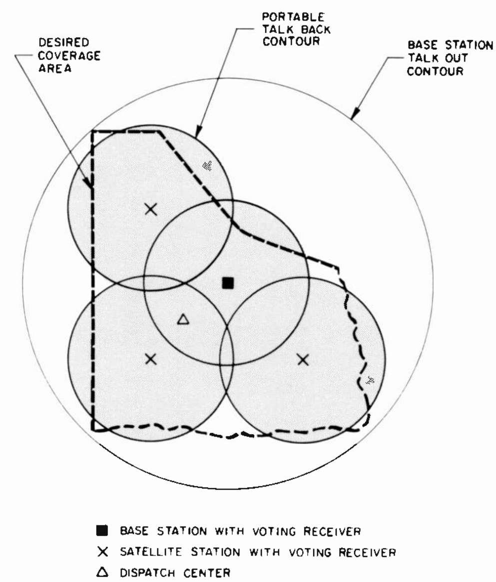


Fig. 1
Strategically located satellite receivers increase the talk-back range of low-power portable and mobile radios.

Receiver voting applications

Mobile and portable transmitters need the extended range possible with the voting system because their output powers are intentionally held to low values to conserve space and power. Voting systems are also generally operated in areas where reception "shadows" exist because of hills, buildings, and bridges.

Fig. 1 shows a typical example of a receiver voting application. In this example, the base-station location and effective output power are selected to provide an adequate signal strength over the desired coverage areas, as shown by the talk-out contour.

Remote "satellite" receiver stations are strategically located to insure that at least one receiver will be within the talk-back range of any portable transmitter within the desired coverage area. The audio output of each satellite receiver is connected by phone line or microwave link to a common point called the comparator station, where the best-quality audio signal is selected. Thus, the talk-back range of portable or mobile transmitters is extended by using phone lines to complete the communication path to the dispatcher. The comparator station is generally located at either the base station or the dispatch center, but can be at any convenient location.

Types of voting systems

Receiver voting systems began to appear in mobile-radio networks in the mid-fifties. Their growth has been steady, with a recent impetus provided by increased use of portable transceivers. Today all major manufacturers of mobile radios offer their own proprietary voting-receiver equipment. The means of selecting the "best" signal for the dispatcher have been refined over the years.

The early receiver voting systems simply selected the first receiver with an input signal above the squelch operating threshold and maintained the initial selection for the duration of the message.

In these systems a new vote occurred with each new message. Known as "race voting," this is unsatisfactory in many situations because in practice the best signal will shift from one receiver to another during a typical message. The recognition of this limitation led to an improved system known as "tone-quantizing."

The tone-quantizing system uses voice-band tones generated at the receiver to represent the quality of the receiver signal, as indicated by the noise quieting.

In this system, the receiver sending the combination of tones representing the "best" signal to the comparator station is selected. Tone-quantizing permits continuous voting in the middle of a message; but in order to conserve tones, the receiver signal is divided into rather large segments, typically 10 dB, which are somewhat coarse. Additionally, the performance suffers because the in-band signaling tones must be filtered from the speech audio.

Tone-quantized voting, through, dòes not account for noise introduced by the phone line.

Because of this noise, it is possible that the dispatcher could be listening to a signal that is not the best available. The limitations of tone-quantized voting led to the development of a technique in which the evaluation circuits operate at the listening or "dispatch" point, thus including telephone-line noise. This eliminated the objections to the previously discussed systems and is now the method of choice on most new designs.

Why use voting receivers?

Because of size and weight limitations, personal two-way radios are low-powered (1 to 6 W compared with 10 to 100 W for vehicle radios). The voting receiver system allows users to increase the range of their lightweight low-power radios by providing a network of intermediate receivers. The signals from these receivers all go to a control point and are "voted" on; the best-quality signal is the "winner" and is selected for listening.

Besides the advantages of keeping personal radios portable, the voting system has another advantage—cost, especially in newly installed systems. Better communication systems can often result from investing in voting equipment, rather than a large number of more expensive radios.

Signal quality is determined differently by different manufacturers.

The most common method of choosing the signal is to simply measure the system noise during speech pauses and select the channel with the least noise as "best." This is satisfactory providing the telephone lines are adjusted and maintained to have the same frequency response and attenuation. RCA uses the ratio of speech peaks to noise quieting during speech pauses as the figure of merit for evaluating signal quality. The advantages of this technique are pointed out in the circuit description.

RCA's receiver voting system

Fig. 2 is a block diagram of a typical voting system. At each of the remote "satellite" stations, a voting-tone encoder (VTE) module encodes a squelch-status tone onto the phone line to the voting comparator equipment panel. This panel has a voting receiver comparator (VRC) module for each satellite receiver and a voting control module (VCM) for each group of receivers operating on the same frequency. When a signal is being received, the audio quality at each VRC is continuously monitored, and the best audio is automatically selected for use by the dispatcher.

Fig. 3 is a block diagram of a single-channel voting receiver satellite station. The voting-tone encoder switches the squelch-status tone onto the phone lines when the receiver is squelched and receiver audio when the receiver is unsquelched. The squelch-status

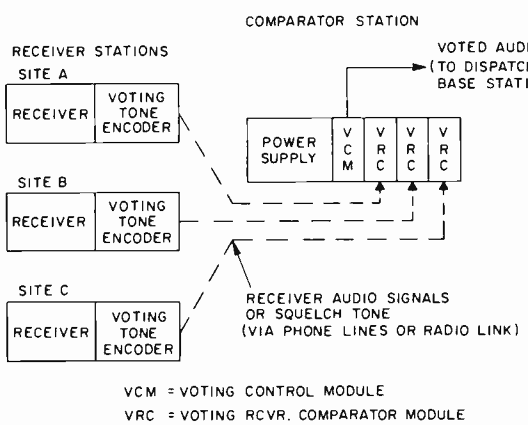


Fig. 2
Each receiver station is connected to a comparator station, where the best audio signal is selected and sent to the dispatcher.

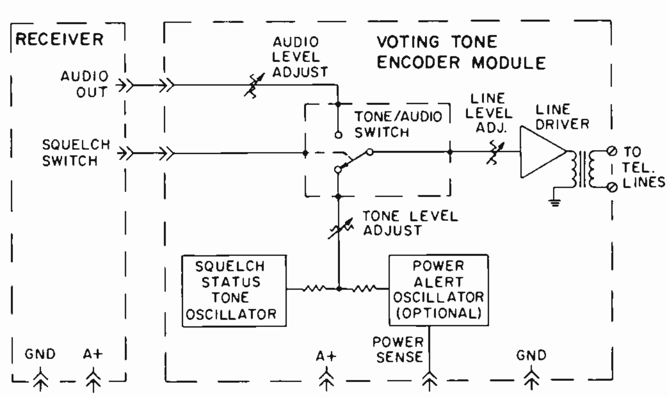


Fig. 3
At the receiver station, a squelch switch is used to switch either receiver audio or the squelch status tone onto the phone line to the comparator station.

tone is used at the comparator station to ensure that an open or shorted line is not voted. The squelch switch in the receiver controls the tone/audio switch. The optional power-alert oscillator warns the dispatcher when the satellite station is being powered by the emergency battery pack.

At the comparator station (Fig. 4), the *S/N* evaluator circuitry provides an output voltage representing the signal-to-noise ratio of the input signal from each receiver. This signal-quality voltage is then compared to ones from all other comparator modules. The module with the "best" signal is then voted by the selection-and-priority circuit and its audio applied to the control module by way of the voted audio switch and the voted audio bus. To ensure that a significant improvement has occurred before the vote changes, the signal-quality voltage of the voted module is artificially enhanced. The selection circuitry of each module works in conjunction with the voting rate timer and ramp generator on the control module, and a priority circuit prevents voting more than one module at a time. The fault-detection circuitry applies a disable input to the voted audio switch control to prevent the closing of the voted audio switch if neither tone nor modulation has been present for a period of five seconds; reception of a squelch tone or modulation enables the voted audio switch control circuitry.

Audio quality considerations

The sole purpose of a mobile communications system is to convey information to and from the dispatcher. To accomplish this task efficiently, an intelligible high-quality audio signal must be maintained. A discussion of speech quality and intelligibility is beyond the scope of this paper, but the interested reader is referred to Ch. 3 of Ref. 1 for an excellent summary of the factors affecting audio quality and the means of relating intelligibility to measurable system parameters by use of the "articulation index."

The voting system was designed to interface with existing equipment that has a signal with more-than-adequate quality and intelligibility for the intended use. Therefore, the design goals were to ensure that the voting system did not cause any appreciable degradation of the audio quality and intelligibility.

To maintain a high-quality voted audio signal, special care was taken to keep the

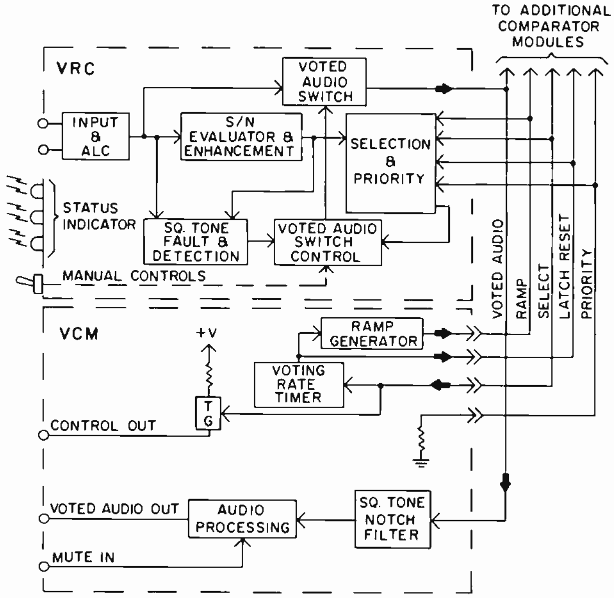


Fig. 4
At the comparator station, a voting control module (VCM) works in conjunction with a voting receiver comparator (VRC) module for each receiver station to select the best-quality audio.

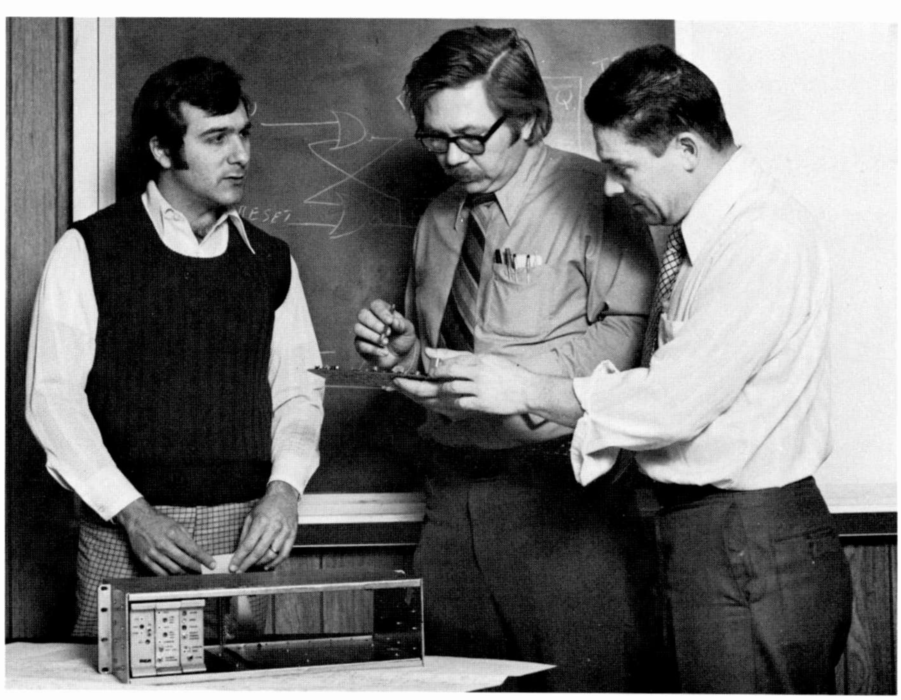
Ron Ferrie joined RCA in 1972 as a member of the engineering staff, working with the Mobile Data Products group. In 1974, became a Leader and was assigned to Portable Products, where he became involved in the VOTEC receiver voting system.

Contact him at:
Portable Products
Mobile Communications Systems
Meadow Lands, Pa.
Ext. 6410

Don Harbert was responsible for the design of the receiver voting system described here. Since writing this article, he has returned to Broadcast Systems at Meadow Lands, where his previous major assignment was project engineer on the TF-25FL transmitter program.

Contact him at:
Broadcast Systems
Meadow Lands, Pa.
Ext. 6354

Authors **Don Harbert** (center) and **Ron Ferrie** (right) with technician Vince Battaglia, who also worked on the voting receiver project. Equipment shown is the voting comparator equipment panel, set up for one-channel, two-site operation.



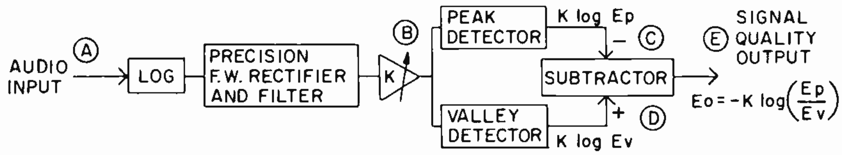


Fig. 5
Signal-to-noise quality evaluation output is a logarithmic function of the ratio of the audio signal during speech to the noise quieting during speech pauses (or signal valleys).

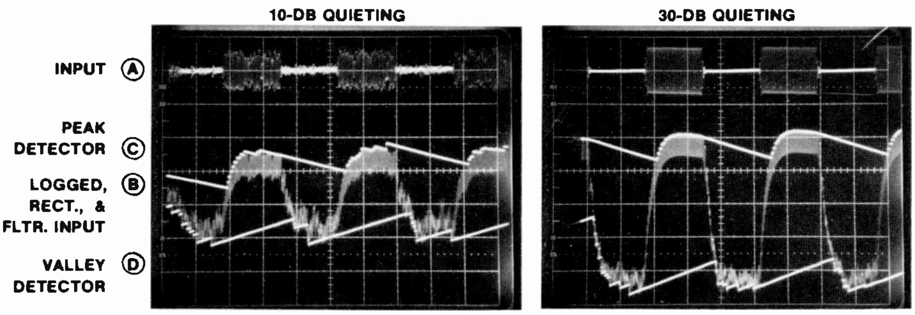


Fig. 6
Signal-to-noise evaluator waveforms here correspond to locations A through D on Fig. 5 for 10-dB and 30-dB quieted signals.

audible switching disturbances when changing votes as low as practical. This was done by using CMOS transmission gates for the voted audio switches and connecting them in such a manner that no dc transients are generated when the switch is opened and closed. In addition, the signals being switched are almost identical, since the ALC circuit at each comparator input sets the audio levels within 2 dB of each other. Changing votes from one module to another occurs in less than one millisecond. Laboratory tests have indicated that abrupt 2-dB changes in the speech signal level cannot be heard with the rate of change normally encountered in a voting system.

The audio distortion was kept below a measured 0.35% for all voting-system modules by properly biasing the CMOS transmission gates used for the audio switches and by using an IC audio power amplifier for the line-driver amplifiers.

The frequency response of the voting system is within 1 dB of the input from 300 Hz to 3 kHz. The system here includes the voting-tone encoder input to the voting-comparator phone-line output with the exception of the notch filter and the telephone-line response. The notch filter has a 30-dB bandwidth of 5 Hz.

From Ref. 2, a 300-Hz to 3-kHz bandwidth provides a maximum articulation index of 0.7, with a corresponding word articulation of 85 of 90%. The voting system reduces this by 3%, for a word articulation of 82.5 to 87.3%. From Ref. 3, the sentence articulation for this word articulation would still be in the 95-100% range, depending on the training of the speakers and listeners.

For low S/N signals, the noise level can be between the threshold of audibility and the minimum speech levels, and so will reduce the articulation index and the intelligibility accordingly. Thus, to provide the dispatcher with the most intelligible signal available, the receiver with the highest speech-signal to noise-floor ratio must be selected.

Signal-quality evaluator

RCA's method of measuring signal quality can be understood by referring to Fig. 5. The log amplifier and precision rectifier and filter generate a signal that is the envelope of the logarithm of the input signal. The envelope signal is then amplified and applied simultaneously to a peak detector and a valley (or noise-quieting) detector. The outputs from both detectors are applied to a subtractor, which is arranged so that its output voltage is $E_o = -K(\log E_p - \log E_v) = -K \log(E_p/E_v)$, where E_p is the output from the peak detector and E_v is the output from the valley detector. Thus, an increasing signal-to-noise ratio will send the output towards ground; a decreasing signal-to-noise ratio will cause the output to go positive. Fig. 6 demonstrates this action by showing typical waveforms at various points in the circuit. C and D are the respective outputs of the peak and valley detectors.

The major advantages of using the speech-peak/noise-quieting ratio for determining signal-to-noise ratio are:

1) The output of the signal-quality evaluator is independent of the input signal level.

2) The output is a logarithmic function of the input-signal/noise-quieting ratio.

3) The true signal-to-noise ratio is measured, which automatically takes into account the transmitter deviation, the noise-quieting at the receiver, and noise introduced by the phone line.

Using the above technique, the evaluator can indicate the input-signal/noise-quieting ratio with an accuracy of 0.6 dB.

Selection circuitry

The method for selecting the comparator with the best-quality audio is analogous to a sample-and-hold technique.

The signal-quality voltage from each comparator module is evaluated periodically, the module with the best audio is "voted," and its audio is switched to the voted audio bus. At the end of the "hold" period, the signal quality of each comparator module is again evaluated. If a module other than the one initially "voted" has a better-quality audio than the original, the vote will change to the module with the best signal. An enhancement circuit does not change the audio quality, only the signal that represents the audio quality. Note that the voted audio switch of the voted module does not open during the evaluation period and will open only if the vote changes. Switching the audio from one module to another occurs in less than one millisecond.

The voting rate, or more precisely the time between evaluations, is adjustable by varying the period of the multivibrator on the control module. The voting rate is set at 50 milliseconds during factory tests, but is adjustable over a wide range. This sample period provides an average of 4 evaluations per syllable.

To select the comparator module with the best-quality audio, a ramp signal is generated in the control module and applied to the inverting input of a threshold detector on each comparator module.

The output voltage from the signal-to-noise evaluator and enhancement circuit is applied to the noninverting input. As the signal quality improves, the signal-quality voltage goes towards ground. When the ramp goes from ground to $+V$, the first threshold detector that detects an equal-magnitude ramp signal and signal-quality voltage will be the module with the best-quality audio.

Fig. 7 gives a description of the evaluator cycle. In the rest state (all receivers squelched), all signal-quality voltages are higher than the ramp threshold, the threshold detector output is high, and the multivibrator is turned offf.

When a receiver in unsquelched, the evaluator voltage goes below V_{TH} and:

- The threshold detector output goes low,
- The S/R flip-flop is set,
- The voting rate timer (M.V.) is started, forcing the ramp voltage to ground, and
- The threhsold-detector output goes high.

At the end of the 50-ms voting-rate timer period, the negative-going edge of the multivibrator output resets the flip-flop, and the ramp voltage starts towards $+V_{TH}$. When the ramp voltage equals the signal-quality voltage on any of the comparator modules, the above sequence repeats. When all receivers are squelched, the ramp voltage goes to $+V$ threshold and remains there awaiting another receiver to unsquelch. Other circuits (not shown) control the voted audio switch and ensure that only one module at a time is voted. The oscilloscope waveforms of Fig. 8 show the signal-quality voltage and the ramp signal at the threshold detector inputs.

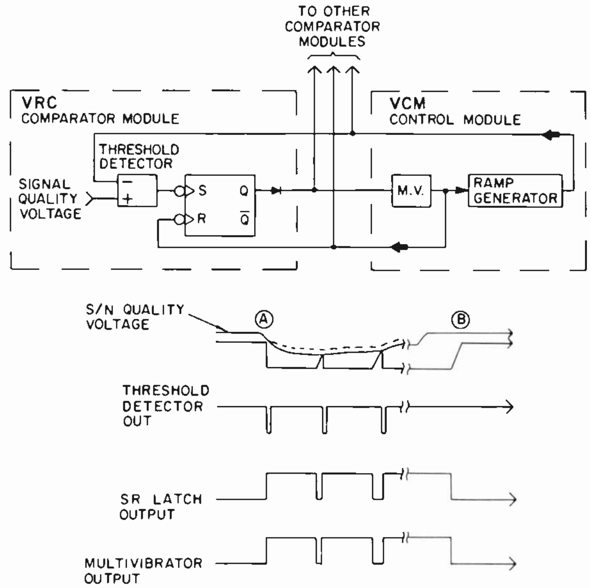


Fig. 7
In the selection circuitry, the ramp generator output is applied to the input of the threshold detector on all comparator modules. The first module with signal-quality voltage equal to the ramp signal will be the one with the best signal quality and hence will be voted. At start of a message (A), signal-quality voltage is lowered to produce an artificial improvement in quality. At end of message (B) signal-quality voltage returns above ramp threshold. Enhancement prevents vote-changing without a significant signal-quality improvement.

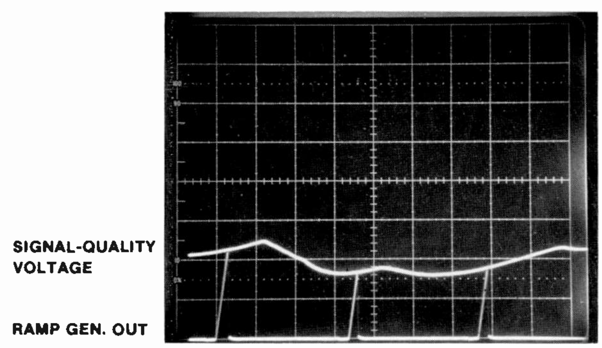


Fig. 8
Selection-circuitry waveforms show interaction between ramp signal and signal-quality evaluator. When the ramp signal and the signal-quality evaluator output (point E of Fig. 5) are equal, the ramp signal is forced low until the next evaluation occurs.

Field tests

RCA Mobile Communications Systems installed a three-site voting system to make tests under actual field conditions as a check on earlier controlled laboratory tests. The voting comparator, one of the satellite receiver stations, and the base station were located at the RCA plant in Meadow Lands, Pa. One of the satellite receivers was located on a hilltop approximately 4.5 air miles northeast of the plant and the remaining site was located at radio station WARO, approximately 7 air miles northeast of the base station. The terrain was hilly, with peaks between 1200 and 1400 feet above sea level and valleys as low as 950 feet above sea level. The base station was at approximately 1000 feet above sea level. The sites and frequency chosen (450-MHz band) produced a test system simulating worst-case field conditions with numerous shadows and blind spots.

During the field tests, both mobile and personal radios were used for talking back to the base. The listening tests were conducted at various vehicle speeds and with a personal radio with the operator standing still and walking.

The field tests verified the laboratory tests by showing that: 1) the talk-back range of the mobile and portable radios was significantly increased by the remote receiver sites; and 2) the best available audio quality was maintained by continuously voting the receiver with the best quality audio. The tests also showed that the voting-rate timer period, the 2-dB enhancement, and the evaluator-circuit time constants established during design and laboratory testing were correct for actual field conditions.

References

1. Hamsher, Donald H. (ed.); *Communications System Engineering Handbook*, McGraw Hill, New York, 1967. See Chapter 3, by Willard F. Meeker.
2. *Op. cit.* pp. 3-15.
3. *Op. cit.*, pp. 3-9, Fig. 11.
4. Meeker, Willard F.; *Private communication concerning syllabic rate and duration of speech pauses for average speech.*

Reprint RE-23-3-5
Final manuscript received September 21, 1977.

Managing RCA Globcom's communication network through automation

With the worldwide communication industry growing rapidly and demanding more sophisticated services, RCA Globcom's management faced future costs of operation rising more rapidly than revenues. Globcom's engineers faced a challenge to reverse the trend; thus, Automated Circuit Management (ACM) was born.

A. Acampora

RCA Globcom is a partner in a worldwide network of copper wire, terrestrial microwave links, submarine cables, and communications satellites.[1] The other partners are private corporations, government-owned or -controlled corporations, and governments themselves.[2].

Operating this international network and resolving its day-to-day problems have been done on a technician-to-technician, office-to-office basis for over a century, but today's network is too large and too fast, and the volume of traffic is too great, for old technology. The network itself has been highly automated to handle the traffic load with line switches and store-and-forward message switches. This paper describes the parameters and rationale for automating the management of the network.

Automation of network management

For automation to be effective, the circuit management scheme must be oriented to automation.

Automation in the communications environment means shifting the circuit control emphasis from continuous manual observation or monitoring to a system of threshold alarms on technical parameters, automatically monitored, with failures only reported. In the plant record area, it means a change from circuit cards and diagrams to route lists and equipment lists, appropriately formatted for fast retrieval on a video terminal. These are substantive changes in operating philosophy that must be accomplished gradually. As each system function is automated, the new procedure must function alongside the old as equipment is changed and personnel are retrained.

Globcom's Automated Circuit Management (ACM) is threefold. First, the operating philosophy must be converted and the threshold alarm system established. Second, an automated data network must be implemented to tie all parts of the system together. And, third, a data base file and management system must be installed. When completed, the system will provide:

- *A central service coordination center* to receive trouble reports and information from sources outside the network.
- *A systemwide data communications network* that will automatically deliver operating information entered by any of the alarms or stations on the network to every other station that *needs to know*, based on a header format containing circuit and service identifiers.
- *A data storage and retrieval procedure* to collect operating data from the communication network and produce exception reports periodically, and on command.
- *An on-line plant record system* that will provide, through remote terminals, circuit and operating records to engineering and operations management on command.
- *Retrieval programs* that will provide service quality and operating statistics from the data base.

If we define a circuit in the communication service as the carrier of information between the terminals of a bearer facility (such as a cable or radio system), we can consider

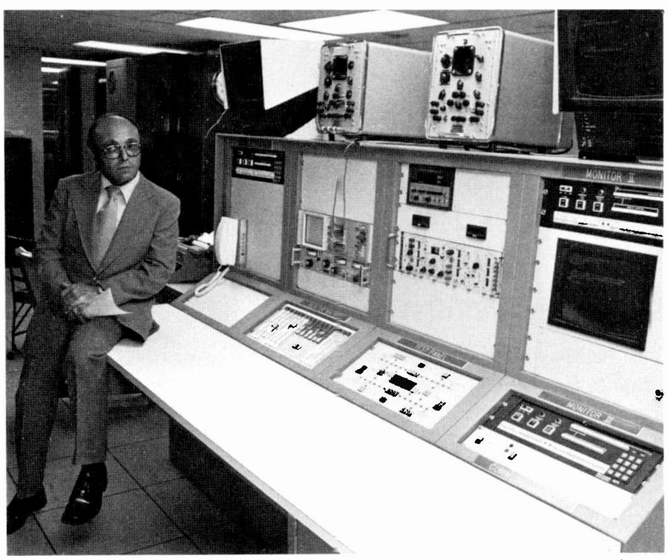


Photo credit: Al Garratt

Author is shown at diagnostic console, which is used to accept the touch-tone channel selectors and specialized signal simulators. At this console, one skilled technician can completely analyze a channel.

Alfonse Acampora has worked in advanced communications for RCA since 1959. His current responsibilities as Staff Engineer include systems planning and wideband transmission disciplines.

Contact him at:
Operations
RCA Global Communications, Inc.
New York, N.Y.
Ext. 2262

the network as a series-parallel combination of circuits, each circuit carrying a share of the telex, telegram, and data communication to all parts of the world. These circuits connect the 15 operating offices of RCA Globcom with each other and with foreign correspondents' offices throughout the world. The offices are equipped with multiplex equipment to derive teletype channels from voice-grade circuits, computer switches to switch telex circuits and to store and forward telegrams, as well as sophisticated storage and switching equipment serving the private networks of a number of large subscribers. This equipment and the transmission networks connecting it are all subject to various faults, which in the classic manual mode of operation are brought to the attention of the operating personnel via the complaint telephone. Each problem is checked and passed from one office to the next until the trouble is located. The record or trouble ticket, kept by pencil, is as cumbersome as it is costly.

Automated Circuit Management is a family of compatible procedures supported and directed by hardware and software.

The procedures for Automated Circuit Management include ordering, implementing, customer filing, circuit routing, and troubleshooting. The hardware includes three computer technologies—intelligent alarms and terminals, a data-communication network, and a data-base storage and management system. The roster of compatible hardware includes input/output devices for various size offices and traffic volumes. Because the system involves automating an already large network without disturbing its day-to-day operation, each segment must be added incrementally and must not adversely affect those functions already automated or those functions still in the manual mode. Continuity in the operating records must be maintained, and the network will grow substantially in size during the two-year period it takes to be fully automated. Where there is any uncertainty, pilot models and pilot procedures are tested before full implementation. Personnel using the system will be trained, sector by sector, as each major segment is added.

Hardware installation

The hardware installation will be implemented in three phases. First is the design and installation of test consoles and alarm sensors. The second phase is the implementation of a data network; third is the implementation of a data-base system. To allow the development and testing of procedures and to start the operating personnel on the learning curve concurrently with the hardware and software procurement, the communication system will be implemented in a limited number of RCA Control Centers using two channels in RCA Globcom's Aircon system.

Phase one is the design and installation of sensors and test consoles.

The RCA Globcom transmission equipment consists of voice control amplifiers, equalizers, and multiplex equipment for deriving teletype channels from the voice bandwidth circuits. Several generations of equipment are represented, ranging from the FDM (frequency division multiplex) racks first installed in the late 1950s to the most modern TDM (time-division multiplex) racks used with the all-digital T-carrier systems. The present-generation equipment has self-test functions and alarm sensors built in. The older equipment relies on pilot lamps and operators to assure proper operation. At the outset of ACM hardware development, sensors must be developed for application to older equipment where none were provided. In many cases, this is a simple carrier detector that is available in the marketplace. Where voice is the communicating medium, or where there are alternate voice and data signals present, simple carrier detectors are inadequate, so we have built energy detectors with settable thresholds to sense the various states expected to be on a circuit. A microprocessor is then programmed to read states of the group of energy detectors on a particular circuit and read out a prepared message to a terminal should it detect a disallowed combination.

A pilot model of a microprocessor-alarm readout has been in operation for several months.[3] This project in the ACM family is a stand-alone that is a fully compatible prerequisite to the planned data communication network and data base system in phases 2 and 3. The second change in methodology is the shift to single-point testing.

Troubleshooting has three separate functions—fault detection, fault isolation, and restoration. Computer-based switches can apply logical tests to the incoming data as well as self testing, and provide readouts which, when coupled with intelligent alarms, detect a large share of the operating problems. Fault isolation requires some manual intervention; nevertheless the time and labor content required to isolate faults can be reduced by the concept of single-point testing—i.e., consoles containing modern semiautomatic transmission-measuring instruments, video terminals for circuit monitoring, and touch-tone selectors to bring circuit ends to the console. Additionally, built-in signal generators and simulators permit one skilled technician to observe and analyze a channel without moving test equipment around the operating center, patching lines, or performing other perfunctory tasks.

These consoles stand alone as diagnostic tools in phase 1, ready to accept the touch-tone channel selectors and specialized signal simulators which follow as the automation program progresses. The basic consoles contain the same instrumentation and communication package for all control centers, but the size and nature of the control center will determine the number of consoles required and the special simulators needed.

Phase two—the implementation of a data communications network—follows the establishment of intelligent alarms and test consoles.

While the data network could stand alone, its effectiveness would not be fully realized. It would be merely an expensive substitute for the telephone and telex. The communications network is a prerequisite to the data-base system because it provides interconnection of the intelligent alarms and consoles beyond the capability of the telephone and telex. The network will reach its full maturity when it interconnects the alarms, consoles, and data base.

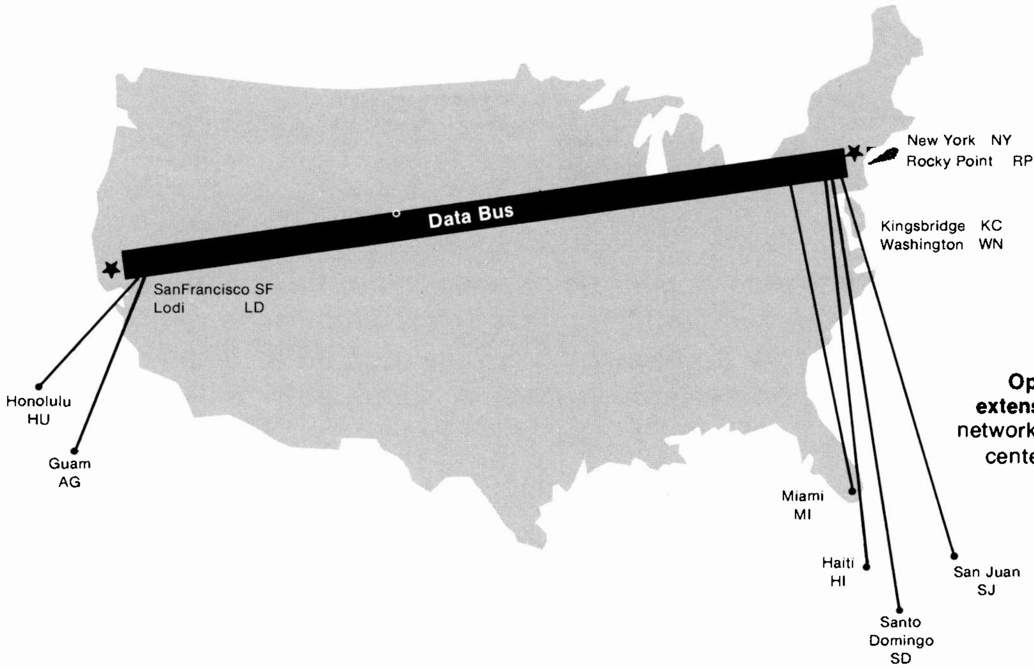


Fig. 1
Operating network and the off-net extension. This data communications network includes 15 Globcom operating centers and operates at data speeds from 300 to 9600 baud.

RCA Globcom has 15 operating centers systemwide, located in the continental United States and at various sites in the Pacific and Caribbean areas. In addition, RCA Globcom has representatives in Europe and Asia who need certain information from the operating system and data base. Fig. 1 shows RCA Globcom's operating network and the off-net extensions. Data speeds range from 300 to 9600 baud, depending on load. The plan is to have a polled network, which is not unique in data communications. RCA Globcom's AIRCON system provides a similar service to the public and will be used to train personnel in automated system procedures.

The third phase of ACM, the data base system, is the keystone of automated operation.

Phases one and two are the prerequisites. The data file is relatively simple. It is a collection of "one liners," each identified by a circuit designator, service designator, and message class. All video terminals, and alarm readouts, as well as the other computers in the system will be directly connected to the data base system through the communications network. The automatic addressing features of the communications networks are intimately related to the storage and processing scheme.

Network operation

All messages entered into the communications network will be addressed and segregated by that network into:

Operational messages to be stored and available for retrieval for a specified interval.

Operational data messages to be stored for quality control or other processed reports.

Plant record data to be stored until withdrawn.

Alarm data to be stored and reported to the operating consoles periodically until cleared.

Implementation schedules.

Emergency bulletin messages.

These messages, identified by service class, will be marked for compilation into daily, weekly, and monthly service reports to management for each service, at a detail level appropriate to the management level and operating requirements. Access to the data base will be controlled by the system which permits each terminal to receive only, enter new material, delete specified files, and access specified files, according to needs and responsibility.

Format discipline and failsafe techniques are mandatory.

The machine-generated inputs will be formatted for the data base, and the system will reject any message which does not fit one of the acceptable formats. Rejections of machine input will be sent to the supervisor of the offending machine. Those data messages formatted to require a response will be re-sent to the addressee until a closeout message is received. Recognizing that no automated system can correct its own failures, the ACM system, like the systemwide network it controls, will be managed, around the clock, from the Service Coordination Center at RCA Globcom's Kingsbridge Communication Center in Piscataway, New Jersey.

Conclusion

The technologies involved in ACM are current state of the art. There is no part that, by itself, has not been done before. Rather, the challenge lies in the combining technologies—hardware and software—and redirecting over 1,000 people scattered from Guam to the Caribbean to do their jobs with new, automated tools without adversely affecting RCA Globcom's communications business.

References

1. Hepburn, J.C.; "RCA Globcom's role as a carrier," *this issue*.
2. Simonds, R.E.; "How the Communications Act affects you," *RCA Engineer*, Vol. 22, No. 4 (Dec 1976|Jan 1977) p. 94.
3. Henn, W.; "Microprocessor automated alarm system," *to be published*.

Acknowledgement

Thanks to R. Ruben, Leader, Operations Design Engineering, for supplying the details of the Test Console development, as well as the photographs used.

Reprint RE-23-3-1
Final manuscript received June 15, 1977.

Computerized inventory management at RCA Records

D. Mishra | A. Devarajan

In the recorded music business, about 10% of the selections produce about 90% of the sales. Should the remaining inventory be held for future sales, sold as distressed merchandise, refurbished, or scrapped?

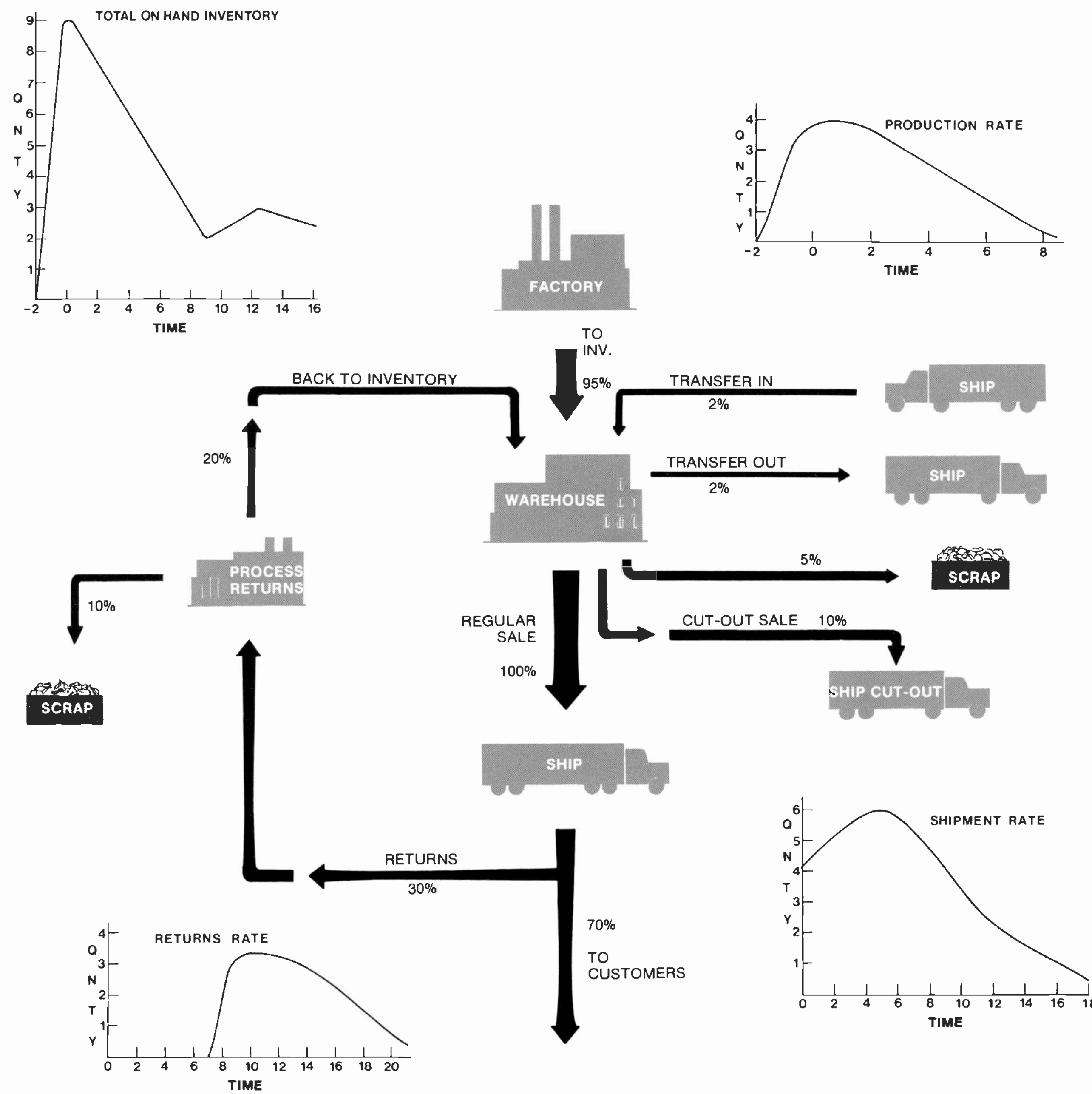


Fig. 1
Recorded-music life cycle has a number of points where decisions must be made—scrap, inventory, or cut-out. Computerized analysis makes the decisions easier and helps keep the on-hand inventory curve at a cost-effective level.

The music business presents an environment where reliable forecasting is not possible, the customer service required is very high, and inventory obsolescence is considerable. Because of this unique environment, a combination of industrial engineering techniques—aging analysis, breakeven analysis, and cost accounting—has been necessary for efficient inventory control, product pruning, and inventory disposition policies.

Unique marketing practices produce volatile inventories

Several industry-wide practices determine the inventory and marketing policies to be followed. For example, products are heavily promoted at their time of introduction, and large distributor orders are booked even prior to publication. This makes it necessary to produce and inventory the product in large quantities at that time. Also, the seller usually gives full credit for the return of unsold merchandise. To give adequate exposure to the product, however, returns are usually allowed only after 60 or 90 days from the purchase date. Since relatively few productions are successful, the practice of giving full credit for unsold returns creates an inventory explosion when the unsuccessful selections are returned.

The industry recently has been attempting to recover a part of the costs sunk on the unsuccessful selections via "cut-out" or distressed-merchandise sales, in which the inventory of unsuccessful selections is sold to specialist merchandisers at very low prices.

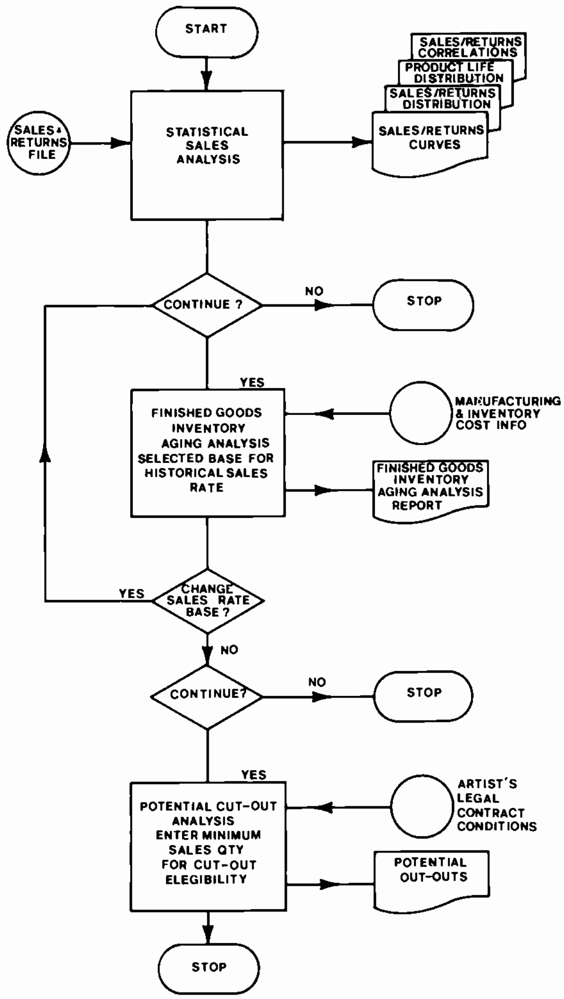


Fig. 2
Sales, aging, and cut-out analyses are the system's three major outputs. Sales analysis can be done by artist, music type, or recording medium, or by sales/return distribution and correlation. Aging analysis and cut-out analysis are explained in Figs. 3 and 4.

Fig. 1 depicts the life cycle of a typical recorded-music product. The production portion of the cycle starts much ahead of sales, and returns lag shipment by a certain period. The nature of the demand life cycle, the extent of returns, and their timing all critically affect the inventories carried after the introduction phase. They also typically determine product profitability and future demands.

The challenges of inventory mangement

Inventory management, in its pursuit of maximum customer service with minimum inventory investment and efficient plant operation, basically attempts to determine how much to order and when. The decision-making process becomes complex because of the unusual characteristics of the recorded music industry stated above. Some of the critical inventory-management functions in this environment are:

Measuring the accuracy of sales forecasting (subjective in the initial stage and semi-quantitative in later stages) and using the feedback for inventory control;

Monitoring the effectiveness and success of new-product introductions by determining sales and returns for individual selections;

Measuring the effectiveness of production and procurement ordering policies;

Identifying sales characteristics and trends of all products in the marketplace;

Tracking the returns from distributors and retailers and establishing guidelines for scrapping or refurbishing returns;

Tracking inventory obsolescence for individual products;

Establishing reserves for future inventory obsolescence for proper matching of revenues and expenses;

Measuring the effectiveness of inventory control by establishing a business plan for investment in inventory;

Creating economical disposition of inactive and obsolete inventories by recommending products to be pruned from the catalog, scrapped from inventory, or sold as distressed merchandise.

The solution—computerized inventory management analysis

In order to achieve effective inventory management, a comprehensive computerized system (Fig. 2) has been developed for problem analysis and decision making. The major components of the system are statistical sales analysis, finished-goods inventory-aging analysis, and product cut-out analysis.

A three-year history of sales and returns is maintained along with detailed product identification.

The total information includes selection number (or part number), title of the product, artist, product medium, type of music, product release date, weekly sales, weekly returns, and inventory classification.

A standard cost file is constructed to include manufacturing cost and inventory-carrying cost by selection number. The "business contractual conditions file" indicates the legal requirements for eventual product disposition, telling if each selection can be dropped from the catalog, sold as distressed merchandise, scrapped, etc. The contractual requirements for disposition of inactive inventory vary considerably from artist to artist.

The classical tools of descriptive statistics are employed to quantify the characteristics of product sales and returns.

Twelve months of data from the day of product release is considered the absolute minimum for statistical significance. The major outputs are the following:

Gross sales and returns curves, which display monthly sales and returns data by selection number and as percentages of corresponding year-to-date figures.

Artist or music type profiles, which present the monthly sales and returns of all the products released by an artist or within a music type.

Product life distribution, which measures the effective product life when the monthly sales value has reached an established minimum. A frequency distribution of product life is developed, along with the arithmetic average and standard deviation.

Sales-returns correlation, computed for the sales and returns by selection number.

Finished goods inventory aging analysis gives information on inventory turnover by selection number.

The on-hand inventory is expressed in months of supply, which is calculated by taking the average historical sales rate over a chosen period as a constant demand for the remainder of the product life. The span over which historical sales are averaged is a critical determinant of the computed inventory age; consequently, sensitivity analyses can be made for different lengths of historical periods.

The aging-analysis method has evolved over the years and proved to be quite effective. It categorizes the types of inventories as follows:

Active = 0-6 months' supply
Surplus = 6-12 months' supply
Obsolete = over 12 months' supply

The system ages individual items of inventory and presents the information by selection number, artist, product medium, and type of music. Fig. 3 shows a typical output.

Product cut-out analysis identifies products that should be dropped from the catalog of active products.

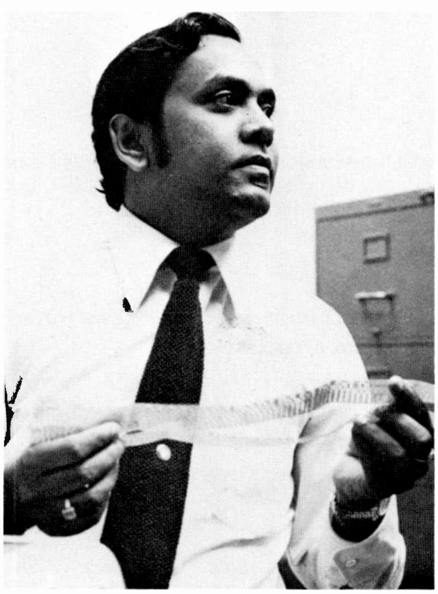
The approach has been to establish an economical annual sales rate for a product line (usually for the type of music—pop, contemporary, rhythm and blues) and declare all selections that fall short of the sales requirements to be eligible for sale as cut-outs, fully recognizing the legal constraints spelled out in the contract with the artist. The recommended list of cut-outs, along with the financial impact on the total business, is furnished to Marketing every quarter for action. Fig. 4 shows a typical output.

Conceptual models for decision making

As an extension of the computerized inventory-management analysis, two mathematical models have been developed to select appropriate strategies for cut-out sales and refurbishment of returns.

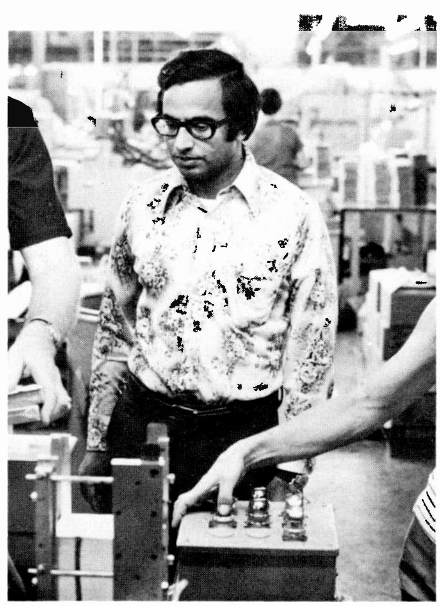
The cut-out model predicts current and future revenues.

A cut-out decision, in the broadest sense, indicates a preference for a large-quantity sale of a selection now (at very low prices) instead of a series of small- or medium-



Dave Mishra is responsible for the Industrial, Manufacturing, and System Engineering Departments at RCA Records. Besides the inventory-management program described here, he has worked on productivity improvement in warehousing and distributing operations, indirect labor control, and automated data gathering.

Contact him at:
Engineering Services
RCA Records
Indianapolis, Ind.
Ext. VT-5368



Dave Devarajan specializes in consultancy-type assignments of a technical/financial nature for RCA Records, using his dual background as an industrial engineer and certified public accountant. He has fifteen years of operational, teaching, and consulting experience in industrial engineering in India and the United States.

Contact him at:
Engineering Services
RCA Records
Indianapolis, Ind.
Ext. VT-5202

SELECTION NUMBER	TITLE	ARTIST	REL. DATE	AV NET SALES	INVENTORY F.G.	R.A.	---PROJECTED INVENTORY DEPLETION--- 1ST 3 MO	2ND 3 MO	3RD 3 MO	4TH 3 MO	OBSOLETE INV.	XS- N/R	# QTR OVR 4
ARL20105	TOSCA	VARIOUS OPERA	73/11	114	781		342	342	97				11.4
ARL20318	GRT RACHMINOF CONCE	CLIBURN, VAN	73/10	44	406		132	132	132	10			4.4
ARL20371	LA BOHEME	LONDON PHIL O	74/09	165	487		487						16.5
ARL20512	AT CARNEGIE HALL	SOLET, JORGE	74/05	32	454		96	96	96	96	70		.7
ARL20553	30 GRT HITS FRM OPERAS	VARIOUS OPERA	74/07	131	223		223						13.1
ARL20637	HANSEL AND GRETEL	HOFFO/LUDWIG	74/08	42	574		126	126	126	126	70		.6
ARL20731	SCHUBERT PIANO TRIOS	RUBINSTEIN, A	75/02	105	513		315	198					10.5
ARL20852	MAHLER SYM #2	LSO/STOKOWSKI	75/11	72	641		216	216	209				7.2
ARL21104	IPHIGENIE [illegible]	VAR CLASSICAL	75/11	32	773		96	96	96	96	389		4.1
ARL21346	GR [illegible]	VARIOUS	76/06	98	722		294	294	194				9.8
ARL214[illegible]	[illegible]	[illegible]OUS	76/06	18	3611		54	54	54	54	3395		62.9
[illegible]	[illegible]	[illegible]TY	76/06	28	1472		84	84	84	84	1136		13.5
		*NET [illegible]	76/10	421	442		442						42.1
			[illegible]05	750	1400		1400					NR	
				582	1028		1028						58.2
ARL40370	I VESPRI SICILIANI	VARIOUS OPERA	74/01	[illegible]	516		516					NR	
ARL41864	LA FORZA DEL DESTINO	PRICE/DOMINGO	77/01	4[illegible]						466	5060		
		PREFIX GROSS TOT			37[illegible]		1368	1368	56[illegible]				
		X-MAS											
		N-RLS											
		*NET PREFIX TOTL			3754		1368	1368	562	99	357		
AWL11671	FIFTH AVENUE & CAROL	TOWNES, CAROL	76/04	5	5780		15	15	15	15	5720		381.3
		PREFIX GROSS TOT			5780		15	15	15	15	5720		
		X-MAS											
		N-RLS											
		*NET PREFIX TOTL			5780		15	15	15	15	5720		

Fig. 3
Aging analysis gives projected inventory by artist or selection. Projections, which can be made by historical sales data or in terms of breakeven inventory years, are used to make inventory policy decisions.

SELECTION NUMBER	TITLE	ARTIST	REL. DATE	CUTOUT DATE	INVENTORY F.G.	R.A.	OBSOLETE INV.	XS- N/R	# QTR OVR 4
ARS10122	DOMINGO CONDUCTS MILNE	DOMINGO/MILNS	73/10	76/09	65		65		.0
ARS10551	GRT SONGS SPEC TV OFFR	BPO/FIEDLER	74/06	76/09	52		52		.0
ARS10614	GRT SONGS TV OFFER	BPO/FIEDLER	74/07	76/09	25		25		.0
		PREFIX GROSS TOT			202		202		
		X-MAS							
		N-RLS							
		[illegible]ET PREFIX TOTL			202		202		
BUS11823	LOOK AT ME NOW	BUCKEYE POL.	[illegible]	77/03	4		4		.0
		PREFIX GROSS TOT			4		4		
		X-MAS							
		N-RLS							
		*NET PREFIX TOTL			1001		1001		
BWS10121	BAND 593 WEST	SIEGEL-SCHWAL	73/10	76/09	1		1		.0
BWS10288	THE LAST SUMMER	SIEGEL-SCHWAL	74/04	76/09	1		1		
BWS10499	SKETCHES	MCDONOUGH, ME	74/06	76/09	26		26		
BWS10791	ZAZU	ZAZU	75/05	77/03	32		32		
		PREFIX GROSS TOT			60		60		
		X-MAS							
		N-RLS							
		*NET PREFIX TOTL			60		60		

Fig. 4
Cut-out analysis identifies products that are no longer profitable and should be dropped from catalog. Outputs can be by selection number (as here) or by artist, type of business contract, or inventory on hand.

quantity sales in the future. Ignoring its external impact, the cut-out decision attempts to trade the future sales contributions and inventory-carrying costs against present revenues.

A product's contributions are defined as its sales price less the direct costs involved in selling, such as commissions, royalties, etc. A decision for cut-out sales will be made only if their contributions will be greater than or equal to all the contributions from future sales and all the carrying cost of future inventory. Sales taking place in the future are discounted to the present value because of the time value of money. The model also accounts for the contribution from scrapping the left-over product and the normal expected rate of return for capital investment.

The scrap/refurbish model gives the number of "breakeven" years for the selections.

In the music business, it is not considered prudent to store a slow-moving selection in the hope that it might become a hot seller with a change of customer taste and/or artist popularity. Given this, the breakeven inventory period should be such that the total cost of the selection stored is equal to the value recovered from the selection.

That is, the expression $V = C_f + nC_i$ gives the breakeven number of years, where C_i is the annual cost of inventory carrying, n is the number of years stored, C_f is the cost of refurbishment, and V is the value received. Value received could be variously defined as:

Regular sales price − direct costs of selling including royalty − scrap value, or

Manufacturing cost − scrap value, or

Cut-out sale price − cut-out sale costs − scrap value

Refurbishment costs will be variable, depending upon the extent of refurbishment involved.

In every case, a decision to scrap or refurbish will be preceded by an inquiry into the breakeven number of years and the demand for the selection for the breakeven number of years. If inventory on hand is greater than the demand during the breakeven number of years, the selection could be summarily scrapped; if lower, it will be refurbished. The demand during the breakeven number of years will have to be appropriately forecasted.

A point to be noted in establishing inventory-carrying costs is the relevance of the components of the total cost factor. We are here considering a product already made, where the cost of production is a sunk cost. In decision making, therefore, the cost of capital does not enter as a factor—no capital will be released as a result of this decision (except to the extent of the value of the scrap). The relevant inventory costs, therefore, are only for storage space, utilities, taxes, etc.

Refinements to the system

The aging-analysis method has been improved.

With the breakeven concept introduced in the scrap/refurbish model above, it follows that the selections that have quantities on hand over the requirements during the breakeven years should be the candidates for product pruning through scrapping or distressed merchandise sales. All the others will produce revenues greater than their inventory-carrying costs and will therefore produce net contributions. In the aging analysis report, selections are arranged in descending order of the number of years that their inventory on hand can satisfy. Marketing can then identify the cut-out from these listings on a qualitative basis. The remaining selections will only produce negative contributions, since their inventory-carrying costs will be greater than the value recoverable from sales. These surplus quantities could be summarily scrapped.

Product pruning tells which selections should be dropped from the catalog.

The aging analysis method described above will identify selections that could be discontinued because of a cut-out or scrap decision. Selections for which the quantity on hand is not large enough to be identified as surplus in the aging analysis will be individually examined at the time of reordering. Selections that are steady movers, selling in medium or large quantities during the year, present no problem. The others will be analyzed to determine if the combination of their ordering costs and inventory-carrying costs will produce a net contribution on a discounted basis. Selections not capable of making any contribution will be discontinued from the catalog.

Selective processing will make handling returns easier.

The refinements in the inventory-management system are scheduled to coincide with a very significant improvement in our returns-handling operations—computerized processing of returns paperwork on a real-time, on-line basis. This would eventually put the power to scrap or refurbish every returned selection on a selective basis within our reach. In this system, operators processing returns at CRT terminals will be fed with direct refurbish/scrap instructions after keying in the selection number and the condition of the return. The scrap/refurbish model will be built into the computer and will make its decision based on the on-hand inventory quantities for that selection.

The benefits

Computerized inventory management has proved to be a powerful tool in minimizing inventory obsolescence as well as in economically disposing of obsolete inventory. We have seen the following tangible benefits:

1) Statistical sales analysis provides a basis for sales forecasting, with the artist profile providing the most important ingredient in forecasting new-product sales. The product-life and returns curves serve as guidelines in forecasting the sales of products that have been in the market for several weeks. Correlation of early returns with sales produces a useful indicator of the expected returns. A measure of the profitability of products released, in terms of units sold, is obtained by analyzing their individual sales and returns performance. The system also identifies the nearly 10% of the selections that account for 90% of the net sales, making them available for suitable marketing and inventory-management decisions.

2) The three-level inventory turnover classification provides a basis for planning investments in inventory and warehouse space. Monthly computation of inventory turnover provides a feedback for inventory control.

3) The monthly aging analysis report highlights inventory obsolescence by individual products. The causes of inventory growth can be analyzed on an exception basis to indicate the effect of subjective forecasting error, production and purchase-ordering policies, and inventory returns. Aging analysis is the key method of determining the magnitude of financial reserves for inventory obsolescence. In addition, the system dictates which selections should be refurbished in the returns process.

4) The product cut-out report enables the inventory-management, marketing, business affairs, and financial operations to judiciously prune products from the catalog. This is especially important because cut-outs have become an aggressively pursued business practice.

Future developments

Our inventory-management system has been presented in an idealized fashion that assumes the completion of systems currently under development. For instance, the monthly aging analysis results are not yet integrated with an on-line returns processing system to allow selective refurbishment of returns on an economic basis. In addition, the breakeven computation for the aging-analysis method remains manual.

The current approach of determining the arithmetic average of historical sales for aging analysis has to be replaced with a weighted-average scheme to forecast future demands. Also, the sales data base lacks an important piece of information—the type and timing of promotional programs. This input will enhance the accuracy of sales forecasting. In addition, normalizing a sales curve in terms of the effective product life remains to be done.

Acknowledgments

Successful computerized inventory management analysis is the result of Messrs. Corya, Egold, and Veleta, whose work made theories and systems pay real dividends.

Reprint RE-23-3-18
This article was originally presented in similar form at the AIIE Systems Engineering Conference, December 1976.

Bi-MOS technology produces a universal op amp

H. Khajezadeh
B.J. Walmsley

New op amp ICs usually only offer performance improvements in one particular problem area. Bi-MOS, the successful marriage of two technologies, has produced an op amp that provides improvements in a number of areas.

Early IC op amps provided the electronics industry with a low-cost functional building block that could be rapidly incorporated into new equipment designs. Because these devices permitted significant reductions in design time and assembly costs, they gained universal acceptance, and several types rapidly became industry standards or commodity items. One such device is the 741, which has been used more widely than any other operational amplifier. The rather modest performance characteristics of these devices limited their use in some applications; however, since equipment designers had become accustomed to using these functional blocks, they simply appended discrete components to the ICs to meet system requirements. Thus, for example, discrete MOS transistor pairs were connected at the input of the standard op amp to improve input impedance, and discrete bipolar transistor stages were added to the output to provide higher current drive.

However, IC manufacturers were busy designing new specialized operational amplifiers to satisfy the more stringent requirements. Operational amplifiers with greater bandwidths were introduced to improve the transient response, input stages were designed with super-beta transistors to improve impedance, and devices were developed for single-supply applications. Each new integrated circuit solved a particular performance problem, but none provided a universal solution.

There is now an op amp, though, the RCA CA3140, that combines many of the performance improvements required by designers in one device; this new device has been made possible by bi-MOS technology (see box on third page of article). This more recent op amp has a very low input current, a high slew rate, a wide common-mode input-voltage range, a wide output-voltage range, and operates from a single supply in the range of 4 to 44 V. See Table I for specifics.

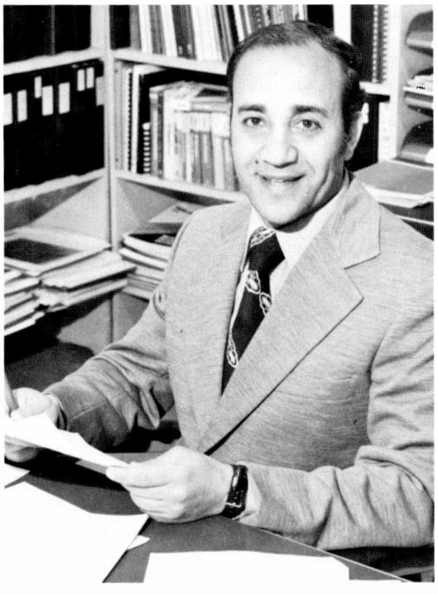
Device description

This operational amplifier has an open-loop gain of 100,000, as shown in Fig. 1. The CA3140 also has the same pin connections as the familiar 741. Fig. 2 gives the op amp's schematic.

The input stage consists of a differential pair of PMOS field-effect transistors with two bipolar n-p-n transistors as loads and two cascade-connected bipolar transistors providing a constant current source of 200 μA. Gate protection and offset nulling features are provided. The gain of the first stage is 10. The input current is typically 10 pA, because of the MOS input transistors, and the input offset voltage is held to approximately the same distribution as a bipolar differential pair by interdigitating the input MOS transistors (Figs. 3 and 4). The second stage uses a bipolar common-emitter transistor with two cascade-connected bipolar transistors as the load. A 12-pF capacitor on the chip provides compensation.

The output stage, which has unity gain, acts as an emitter follower for sourcing current and as a saturated transistor for sinking current. A unique "dynamic current sink" causes the heat-sink current

Heshmat Khajezadeh has been Manager of Bipolar Integrated Circuits Engineering at the Solid State Division since 1974. He has received the David Sarnoff Award for Outstanding Technical Achievement and the RCA Engineering Achievement Award for significant contributions to integrated-circuit technology.
Contact him at:
Bipolar Integrated Circuits Engineering
Solid State Division
Somerville, N.J.
Ext. 6795



Bruno Walmsley has 26 years of engineering experience, sixteen of them with the Solid State Division. He has worked on all aspects of testing and test systems development for linear and digital integrated circuits. He is presently Manager of Bipolar Applications and Test technology at Somerville.
Contact him at:
Bipolar Applications and Test Technology
Solid State Division
Somerville, N.J.
Ext. 6199

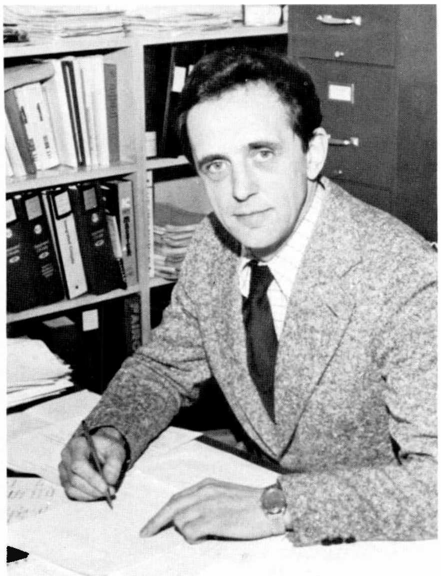


Table I
Typical characteristics of the CA3140 at V+ = 30 V and V- = 0 V.

Input current I_{IN}	10 pA
Slew rate	9 V/μs
Gain bandwidth	4.5 MHz
Common-mode input range	−0.5 to +27.5 V
Output swing	0.6 to 27.5 V
Open-loop gain	100 dB
Common-mode rejection ratio	90 dB
Output current source	20 mA
Output current sink	20 mA

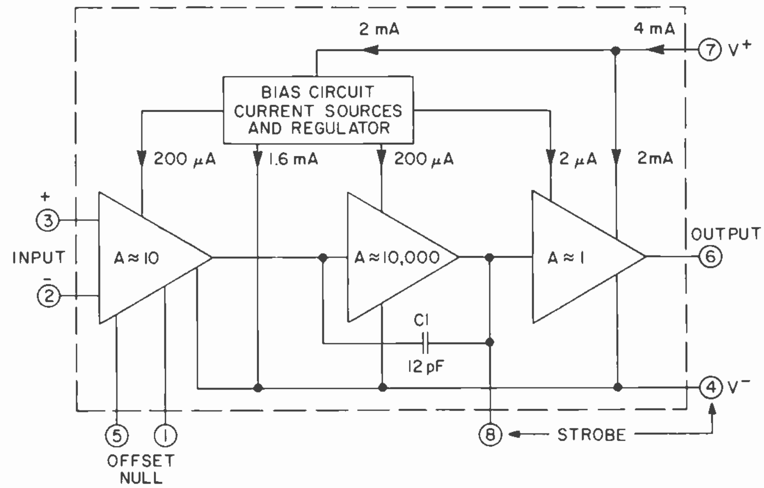


Fig. 1
CA3140 has pin connections identical with the standard 741 op amp.

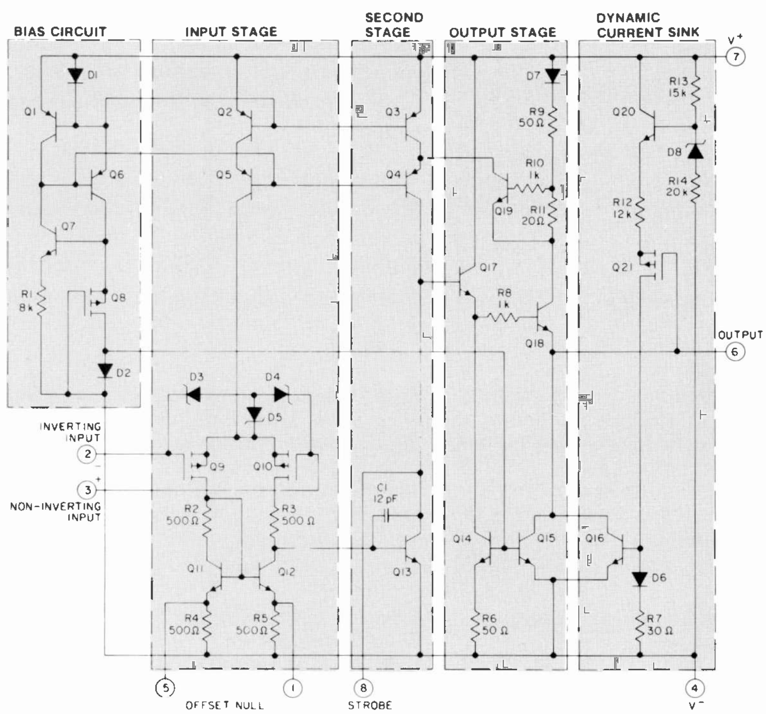


Fig. 2
"Dynamic current sink" after output stage has the current to the sink increase as the output voltage falls.

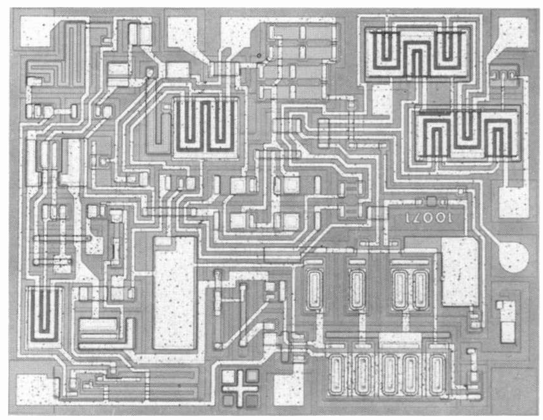


Fig. 3
Interdigitated input MOS transistors are used to approximate the input offset voltage distribution found with a bipolar differential pair.

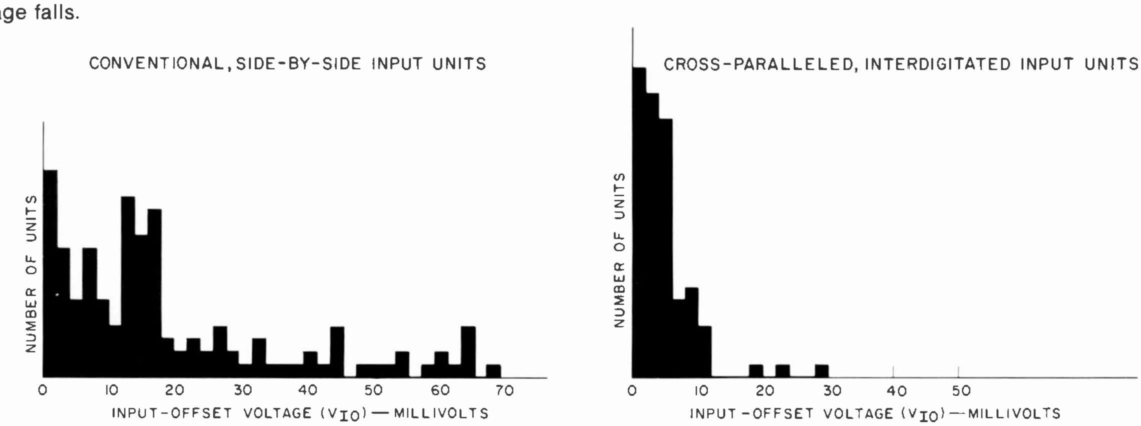


Fig. 4
Good input offset voltage distribution is a result of using interdigitated input transistors.

to increase as the output voltage falls. The output stage will sink or source 20 mA of current and, hence, is capable of driving capacitive loads at high slew rates. The output voltages will swing typically to within 2.5 V of the positive supply voltage and to within 0.6 V of the negative supply voltage, with a load of 2 kΩ.

A bias circuit regulates all of the critical current sources in the amplifier and renders its characteristics largely independent of supply-voltage variations.

Applications

Three typical circuit applications for the CA3140—transistor or thyristor driver, current amplifier, and zero-crossing detector—demonstrate some of its features.

Fig. 5 demonstrates the CA3140's ability to switch a transistor or thyristor directly, with low $V_{CE\ sat}$ (0.06 V at 10 μA), while operating from a single supply.

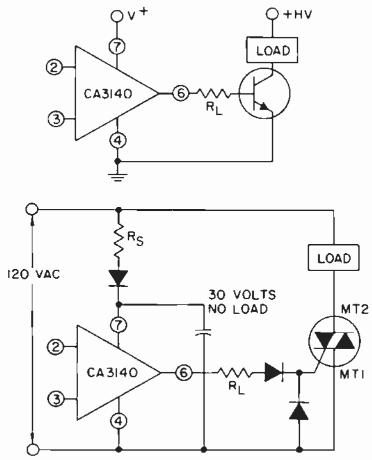


Fig. 5
Direct thyristor/transistor switching is possible with this configuration.

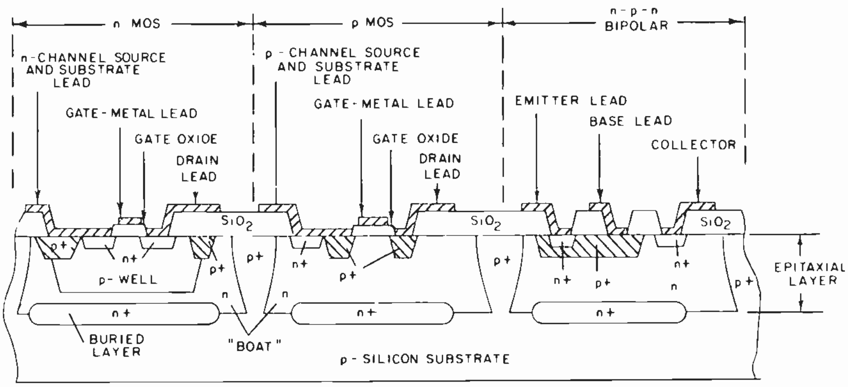
What is bi-MOS technology?

Bi-MOS is a cost-effective technique for combining MOS and bipolar devices in a monolithic chip without compromising the electrical characteristics of either device type. The bi-MOS process requires the same number of photosteps as the conventional compensated operational-amplifier process. However, the requirement of the MOS process for a drift-free, low threshold voltage must not be allowed to alter the electrical characteristics of the bipolar devices.

The basic bi-MOS process uses (100) crystal, which helps maintain low levels of built-in charge and a low p-channel threshold without the need for a special boron implant in the channel areas. Low-temperature HCl and steam oxidation are used to form the clean, sodium-free channel oxide without disturbing the bipolar diffusions. Short-term, high-temperature annealing reduces the level of built-in charge produced by the low-temperature oxidation.

Aluminum metallization is evaporated in a clean E-gun system to produce devices with maximum threshold stability. The base, emitter, and channel oxide cuts are all tapered to assure reliable metal coverage.

Cross-paralleled interdigitated transistors are used to match the PMOS pairs closely and to assure a low temperature coefficient of input offset voltage. Fig. 4 shows how this structure improves input offset-voltage distribution.



Cross section of bi-MOS chip shows CMOS FETs and n-p-n bipolar transistor.

Fig. 6 shows the CA3140 in a current-amplifier circuit measuring very small currents. The CA3140 can be used in this application because its input current (10 pA) is much lower than the current being measured. This is because the CA3140 operates from a single supply, so one of its inputs can be used as a ground reference.

The zero-crossing detector circuit (Fig. 7) senses an input signal and switches the output each time the input crosses zero.

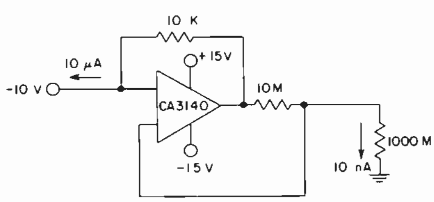


Fig. 6
Current amplifier circuit takes advantage of CA3140's low input current.

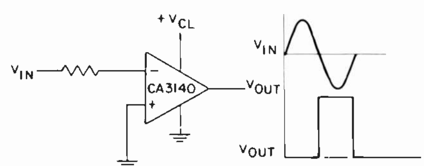


Fig. 7
Zero-crossing detector circuit is based on the CA3140's single-supply operation; one input is used as a ground reference.

Summary

Bi-MOS technology has produced a monolithic operational amplifier, the CA3140, with significantly improved characteristics. This innovation provides designers with an inexpensive monolithic operational amplifier with the flexibility to be used in many applications.

Reprint RE-23-3-12
Final manuscript received December 12, 1976.

A single-wire alarm system using the COSMAC microtutor

T.F. Lenihan

A microprocessor-controlled single-wire burglar alarm system gives the user the benefits of standard multiwire systems, but has additional flexibility and is simpler to install.

Mulitwire alarm systems can easily identify the entry point in an alarm system, but they are expensive and installation is complex. Conventional single-wire systems, while inexpensive and simple to install, cannot pinpoint exactly where the breech has occurred. However, by using a series string of resistors around the perimeter that is being protected, and taking advantage of the voltage divisions present in such an arrangement, it is possible to detect the exact entry point while retaining the ease of installation inherent in single-wire systems.

Hardware

Fig. 1 shows a basic alarm circuit that combines ease of installation with the ability to locate the entry point. Although it is a single-wire system, the analog/digital (A/D) converter can identify the exact location where an intrusion takes place. This arrangement uses a resistor/switch combination at every door and window being protected. A different value resistor is placed across each switch in a series arrangement of switches. When a switch is activated, a unique voltage is read across the sensing resistor, R_s, which is shown returned to ground.

However, I found that this simple arrangement works for only about four entry points, i.e., four resistor-switch sensors, before the system breaks down. In practice, the string of resistors must be fed by a constant-current generator. By holding the source voltage and current to constant values, and by varying the resistance alone, the error voltage is developed across the constant-current source. Now we have a system that will cover a multitude of entry points, albeit one that lacks flexibility. For example, entry points intentionally left open cannot be ignored in this system. By adding a microprocessor to the A/D system, this flexibility can be achieved with software. For example, the microprocessor program could be written to disregard a

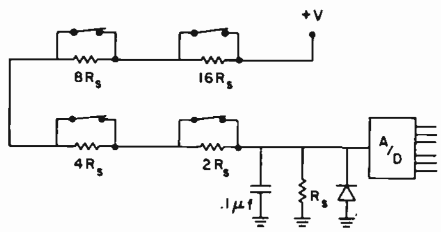


Fig. 1
Simple resistor-switch loop system with only an A/D converter works as a single-wire system, but with limited flexibility.

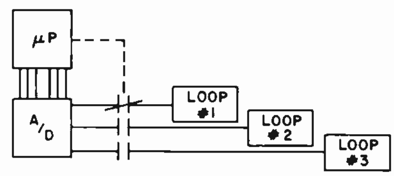


Fig. 3
Single-wire alarm system with A/D converter plus microprocessor can be expanded easily to a multiloop system by having the microprocessor poll each loop.

Legend

Component	Manufacturer
K,L — CD4042	RCA
J — CD4001	RCA
A,B — CD4006	RCA
C — ADC-82	Burr-Brown
D — CD4514	RCA
E,F — µA7805	Fairchild
H — CD4013	RCA
Diodes — IN914	ITT
Q1,Q2 — 2N6387	RCA

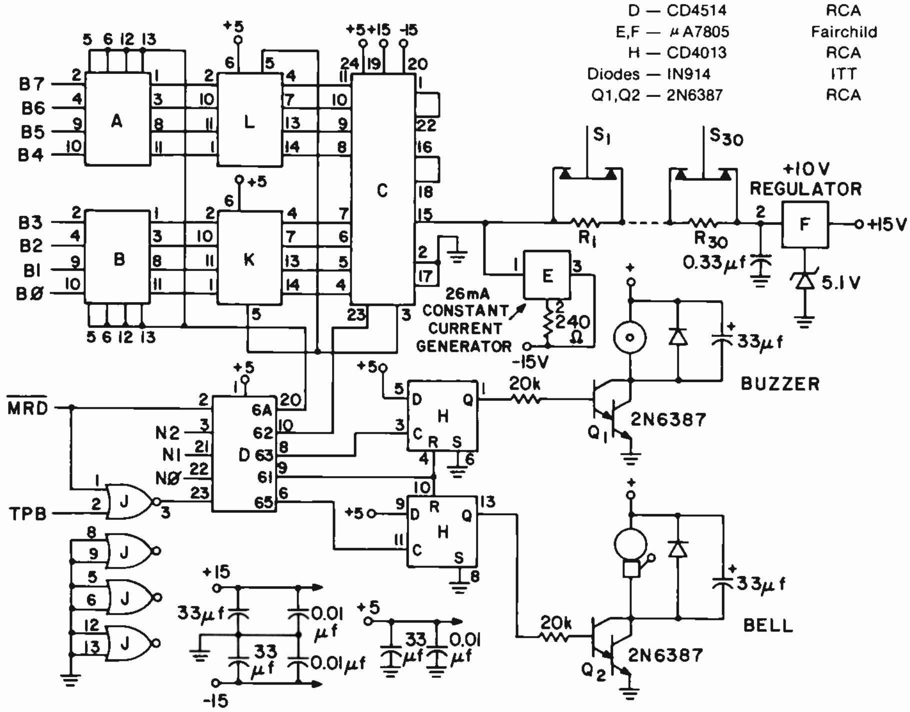


Fig. 2
Schematic of alarm interface board shows microtutor data bus connections B0-B7, input/output signals N0, N1, N2, and timing control signals MRD and TPB available at the external device connector of the COSMAC microtutor. In a multiloop system, only resistor-switches S1 through S30, the constant-current generator, and 10-volt regulator would need to be duplicated for each loop.

window intentionally left open for ventilation, or perhaps, for a door under repair.

The circuit shown in Fig. 2 interfaces directly with a COSMAC microtutor and will protect about 30 entry points. It consists of a 26-mA constant-current loop monitored by an 8-bit A/D converter. The output of the A/D is latched for input to the central processing unit. The output portion consists of a warning buzzer and alarm-bell circuit. The diodes and capacitors in this section are needed for coil suppression. The circuit uses one input and four output strobes decoded by the CD4514. Another application for this circuit is for use as a keyboard. The cost of the A/D package is $55 in unit quantities. I should point out that in the simplest form of the circuit, the microprocessor could be replaced by hardwired logic. Again, however, the flexibility of the system would be lost.

An expansion of the system organization for protecting larger areas is shown in Fig. 3 In this multiloop scheme, the microprocessor sequentially polls several lower-resolution loops. This system will lower costs, because the resistor at each entry point can have a wider tolerance, and also improve reliability because cutting one wire will not incapacitate the entire system.

Software

Fig. 4 is a flowchart of the COSMAC microtutor program for the burglar-alarm system. The circuit is reset immediately upon starting and, after a 20-second delay (to enable you to exit), the program reads the A/D latch. To provide a useable margin between adjacent readings, the input byte is shifted three times to the right. To protect against random noise spikes, the program requires 15 consecutive non-zero readings before it advances to the output mode. In the output mode, the entrance number is displayed in hex notation on the microtutor and the warning buzzer is activated for 20 seconds. If the "in" switch is not pressed within 20 seconds, the alarm bell is activated. Pressing "in" resets the alarm and restarts the program after a 20-second delay.

The program activates the warning buzzer to alert you to reset the alarm before the bell goes off (if you are entering) or to indicate to an intruder that a circuit has been tripped before entry has been fully gained. Hopefully, this initial alarm will scare off the intruder.

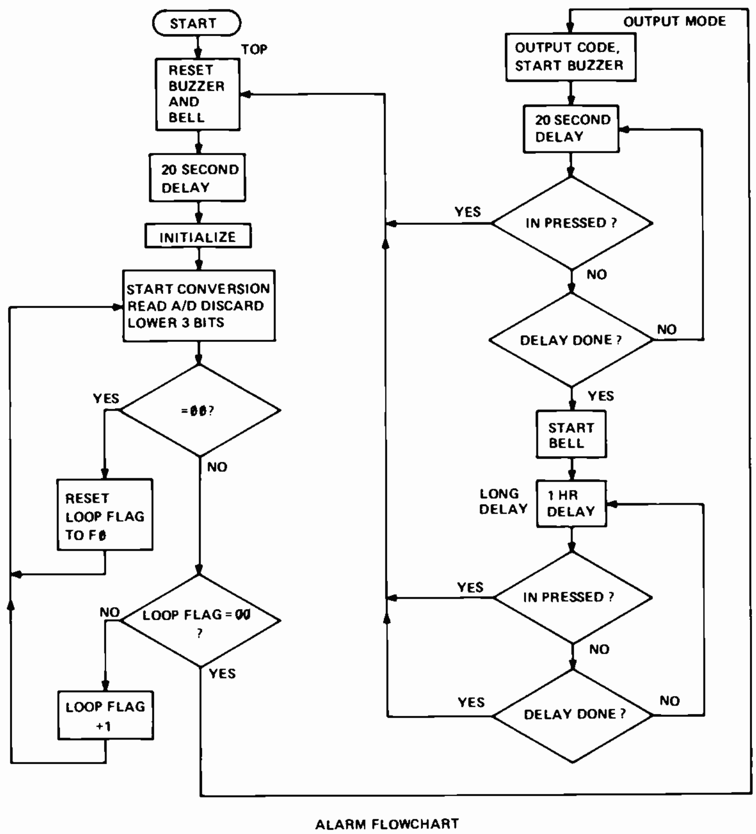
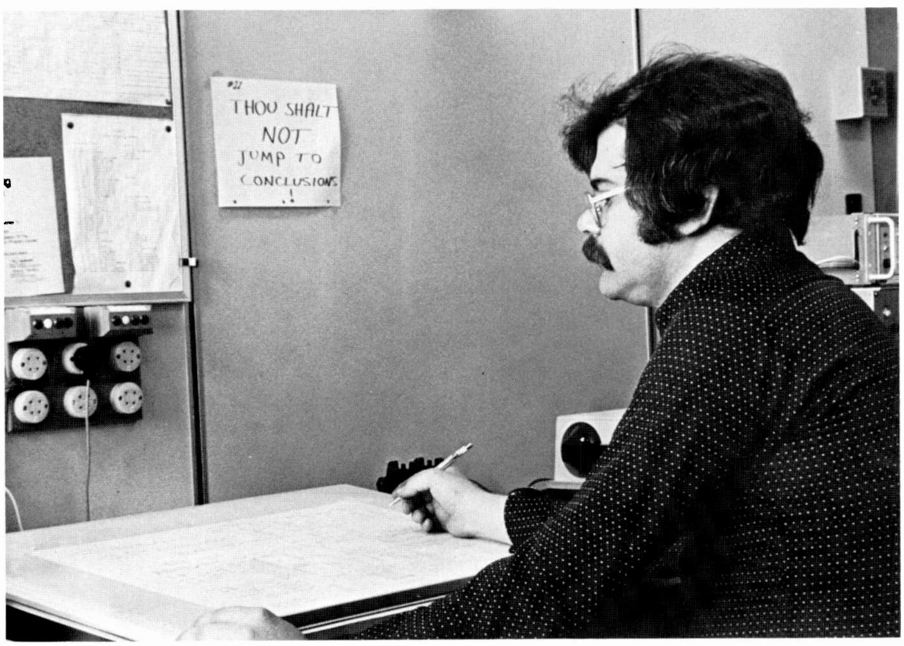
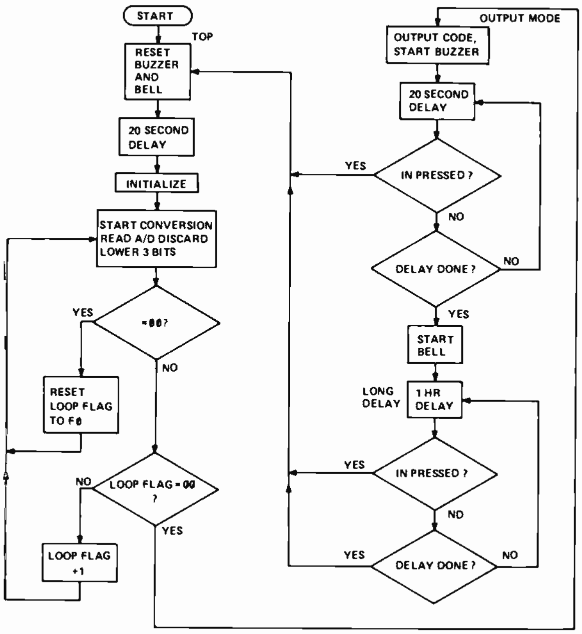


Fig. 4
Flowchart for single-wire alarm system. Program steps in this chart are detailed in Table II.

Tom Lenihan works in the TV Microsystems Research group at RCA Laboratories. He is presently involved in applying microprocessors to consumer electronic products and automatic testing systems. Tom's idea for a novel way to use RCA's COSMAC microprocessor won second prize in the "COSMAC Applications Contest," sponsored by Solid State Division in conjunction with the *RCA Engineer*. If you are interested in building the system described in this article and need more information, Tom will be glad to help you. Contact him at:
TV Microsystems Research
RCA Laboratories
Princeton, N.J.
Ext. 3218





ALARM FLOWCHART

Table I
Microtutor register assignments used in the alarm-system program.

R0 = Program counter
R3 = Data pointer
R4 = Loop flag
R5 = Short delay counter
R7 = Long delay counter

Delays are based on clock speed of 1.72 MHz. Change M004E to vary alarm on-time in 1-min increments, e.g.:

0A = 10 min
0F = 15 min
1E = 30 min
2D = 45 min
3C = 60 min

Table IIa
Actual alarm-system program is shown in first set of data below. Second set of data (Table IIb) ties in with flowchart (top left) and shows what event occurs at a particular instruction byte in that memory location (M).

Memory byte (M)	**Instruction byte (m)**							
0000	D0	E0	61	00	F8	FF	B5	A5
0008	F8	0F	FF	01	3A	0A	25	95
0010	3A	08	F8	00	B3	F8	FF	B5
0018	A5	F8	67	A3	F8	00	B4	F8
0020	F0	A4	E0	62	00	E3	6A	F0
0028	F6	F6	F6	53	32	49	84	32
0030	34	14	30	22	E0	63	00	E3
0038	64	23	F8	0F	FF	01	3A	3C
0040	25	37	01	95	3A	3A	65	30
0048	4D	64	23	30	1C	F8	3C	A7
0050	B7	F8	FF	A5	B5	F8	2F	FF
0058	01	3A	57	25	37	01	95	3A
0060	55	27	87	3A	51	30	01	

Table IIb

Algorithm	**M**
Top	0001
Reset bell & buzzer	0002
20-second delay	0004
Initialize	0012
Start conversion	0022
Read A/D	0026
Shift right 3 times	0028
Store	002B
= 00?	002C
If yes, read again, fix pointer	002D
If no, check loop flag	002E
= 00?	002F
If yes, go to output mode	0030
If no, increment flag, read again	0031
Output mode	0034
Start warning buzzer	0035
Output code	0037
Delay 20 seconds	003A
Reset?	0041
If yes, go to top	0042
If no, continue delay	0043
Start bell	0046
Go to long delay	0047
Output code	0049
Go to read again	004B
Long delay	004D
Set up counters	004E
Change value at M004E	0050
To vary alarm time	0051
1-hour delay	0054
Decrement counter	005B
Reset?	005C
If yes, go to top	005D
If no, continue	005E
Decrement counter	0061
Done?	0063
If no, count again	0064
If yes, go to top	0065

Table III
Resistance values for each entry point to be protected in single-wire alarm system.

Resistance value (ohms)	*Entry point number (hex readout)*	*Resistance value (ohms)*	*Entry point number (hex readout)*
33	01	390	10
47	02	420	11
75	03	440	12
100	04	470	13
120	05	500	14
150	06	530	15
160	07	550	16
200	08	570	17
220	09	600	18
240	0A	630	19
270	0B	660	1A
290	0C	680	1B
310	0D	710	1C
340	0E	750	1D
370	0F	820	1E

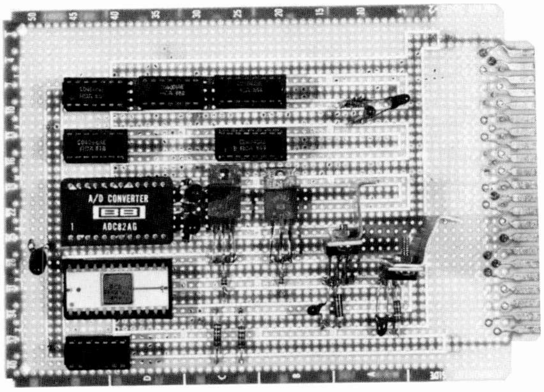


Fig. 5
Component side of burglar-alarm interface board shows homebrew L-shaped aluminum brackets used as heat sinks for the 10-volt regulator (left) and constant-current generator (near contact side of board). The two transistors in the center are power darlingtons for driving the bell and buzzer.

The bell will reset and re-arm automatically one hour after going off, so that if you are away for an extended period, the bell will not ring continuously until you return. A notice to this effect should be posted conspicuously for the police.

The software for implementing this program is shown in Tables I and II. The software was written to accommodate both the CDP1801 and the CDP1802 versions of the microtutor. If the CDP1801 version is used, change the 64 instructions at M(0038) and M(0049) to 60.

The code 00 is the normal closed-loop reading. Any other reading indicates a breech of the system. The unique code 1F indicates that the system wire has been cut.

Construction hints

The ±15-volt power supplies to the A/D converter should be bypassed as close to the package as possible and the μA 7805 regulators should be installed with a small heat sink attached as shown in Fig. 5. The original board was wire-wrapped on a Vector plugboard for direct insertion into the microtutor external socket. A later version (Fig. 6) used a microtutor extender board. If magnetic switches are used, they should be of the type which are normally open (contacts apart). Using the resistance values shown in Table II, the unit will monitor 30 doors and windows, a combination covering most houses. All values in Table III were determined using standard 5% resistors. Fig. 7 shows a typical installation of switches throughout a house.

Reprint RE-23-3-19
Final manuscript received November 10, 1977.

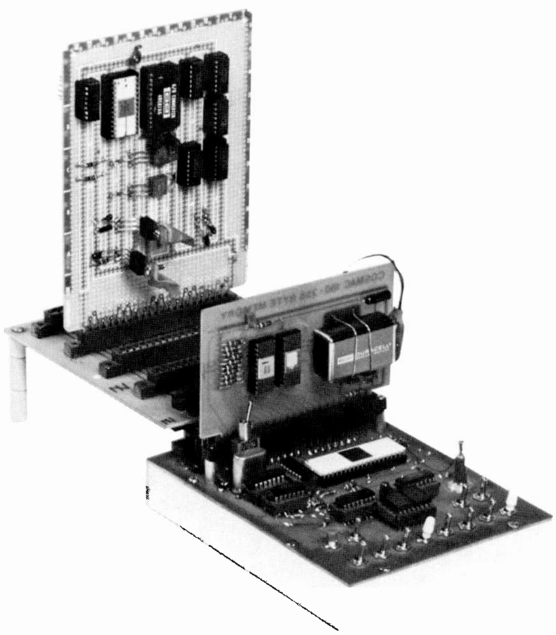


Fig. 6
Integrated system includes alarm interface board mounted in a microtutor extender board and connected to a COSMAC microtutor.

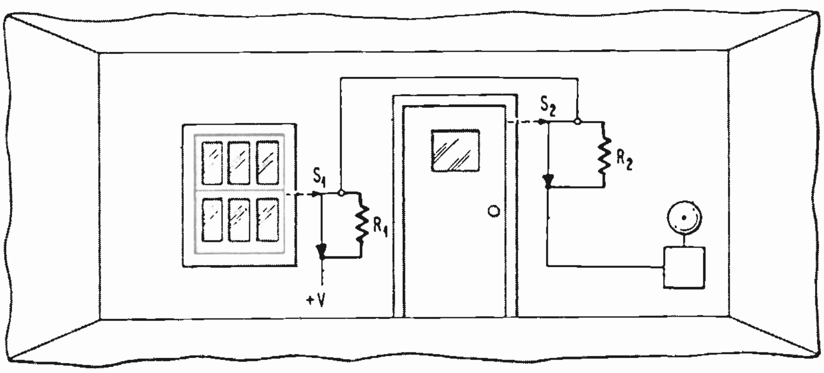


Fig. 7
Typical installation of resistor switches throughout a house in a single-wire alarm system. Magnetic switches, if used, should be of the normally open type.

Dates and Deadlines

Upcoming meetings

Ed. Note: Meetings are listed chronologically. Listed after the meeting title (in bold type) are the sponsor(s), the location, and the person to contact for more information.

DEC 5-7, 1977 — **Natl. Telecommunications Conf.** (IEEE *et al*) Marriott Hotel, Los Angeles, CA **Prog Info:** Stanley A. Butman, 4800 Oak Grove Dr., Pasadena, CA 91103

DEC 5-7, 1977 — **International Electron Devices Mtg.** (IEEE) Washington Hilton, Washington, DC **Prog Info:** Courtesy Assoc./Susan Henman, 1629 "K" St., NW, Washington, DC 20006

DEC 5-7, 1977 — **1977 Winter Simulation Conf.** (IEEE) Natl. Bureau of Standards, Gaithersburg, MD **Prog Info:** R.G. Sargent, Dept. of Industrial Eng. & Operations Research, Syracuse Univ., Syracuse, NY 13210

DEC 15, 1977 — **Computer Networks: Trends & Applications** (IEEE, NBS) Natl. Bureau of Standards, Gaithersburg, MD **Prog Info:** Computer Networks, PO Box 639, Silver Spring, MD 20901

JAN 16-18, 1978 — **Integrated & Guided Wave Optics** (IEEE, OSA) Salt Lake Hilton, Salt Lake City, UT **Prog Info:** Amnon Yariv, Calif. Institute of Tech., Pasadena, CA 91109

JAN 24-26, 1978 — **Reliability & Maintainability** (IEEE *et al*) Biltmore, Los Angeles, CA **Prog Info:** D.F. Barber, PO Box 1401, Branch PO, Griffiss AFB, NY 13441

FEB 7-9, 1978 — **Laser and Electro-Optical Systems II** (IEEE, OSA) Town and Country Hotel, San Diego, CA **Prog Info:** Jon Hagan, Optical Society of America, Suite 620, 2000 "K" St., NW, Washington, DC 20006

FEB 13-15, 1978 — **WINCON (Aerospace & Electronic Systems Winter Convention)** (IEEE) Los Angeles, CA **Prog Info:** Max T. Weiss, The Aerospace Corp., PO Box 92957, Los Angeles, CA 90009

FEB 15-17, 1978 — **Intl. Solid State Circuit Conf.** (IEEE, U. of Penn.) Hilton, San Francisco, CA **Prog Info:** Mark R. Barber, Bell Labs., 600 Mountain Ave., Murray Hill, NJ 07974

MAR 21-28, 1978 — **Industrial Applications of Microprocessors** (IEEE) Sheraton, Philadelphia, PA **Prog Info:** W.W. Koepsel, Dept. of E.E., Seaton Hall, Kansas State Univ., Manhattan, KS 66505

MAR 22-24, 1978 — **Vehicular Technology Conf.** (IEEE) Regency Hotel, Denver, CO **Prog Info:** John J. Tary, U.S. Dept. of Commerce, OT/ITS, 325 Broadway, Boulder, CO 80302

APR 3-7, 1978 — **Design Engineering Conf. and Show** McCormick Place, Chicago, IL **Prog Info:** Tech. Affairs Dept., ASME, 345 East 47th Street, United Engrg. Ctr., New York, NY 10017

APR 4-6, 1978 — **Private Electronic Switching Systems Intl.** (IEEE, IEE) IEE, London, England **Prog Info:** IEE Conf. Dept., Savoy Place, London WC2R OBI, England.

APR 4-7, 1978 — **Communications '78 (Intl. Exposition of Communications Equipment & Systems)** Birmingham, England **Prog Info:** Exhibition Director, Tony Davies Communications, c/o Industrial & Trade Fairs Ltd., Radcliffe House, Blenheim Court, Solihull, West Midlands B91 2BG, England

APR 10-12, 1978 — **Acoustics, Speech and Signal Processing** (IEEE) Camelot Inn, Tulsa, OK **Prog Info:** Rao Yarlagadda, School of Elect. Engineering, Oklahoma State Univ., Stillwater, OK 74074

APR 24-26, 1978 — **Electronic Components** (IEEE, EIA) Disneyland, Anaheim, CA **Prog Info:** John Powers, Jr., IBM Corp. Hdqtrs., Dept. 836 IB, 43 Old Orchard Rd., Armonk, NY 10504

MAY 10-12, 1978 — **Conf. on Software Engrg.** (IEEE, NBS) Hyatt Regency Hotel, Atlanta, GA **Prog Info:** Harry Hayman, Conf. on Software Engrg., PO Box 639, Silver Spring, MD 20901

MAY 16-18, 1978 — **NAECON (National Aerospace & Electronics Conf.)** (IEEE) Dayton Convention Ctr., Dayton, OH **Prog Info:** NAECON, 140 E. Mounument Ave., Dayton, OH 45402

MAY 17-19, 1978 — **Circuits & Systems Intl. Symp.** (IEEE) Roosevelt Hotel, New York, NY **Prog Info:** H.E. Meadows, Dept. of Elec. Engineering & Computer Science, Columbia Univ., New York, NY 10027

MAY 23-25, 1978 — **Electro/78** (IEEE) Boston-Sheraton, Hynes Auditorium, Boston, MA **Prog Info:** W.C. Weber, Jr., IEEE Electro, 31 Channing St., Newton, MA 02158

Calls for papers

Ed. Note: Calls are listed chronologically by meeting date. Listed after the meeting (in bold type) are the sponsor(s), the location, and deadline information for submittals.

May 1-3, 1978 — **Microwave Power Tube Conf.** (IEEE, DOD) Naval Postgraduate School, Monterey, CA **Deadline Info: (ab) 2/1/78 to** Leonard H. Klein, Palisades Institute for Research Services, Inc., 201 Varick St., New York, NY 10014

MAY 17-19, 1978 — **1978 Carnahan Conf. on Crime Countermeasures** (IEEE, U. of Kentucky) Carnahan House, Lexington, KY **Deadline Info: 1/16/78 to** John S. Jackson, College of Eng., U. of Kentucky, Lexington, KY 40506

MAY 29-JUN 1, 1978 — **Intl. Quantum Electronics Conf.** (IEEE, AIP) Atlanta Hilton, Atlanta, GA **Deadline Info: (35-wd ab and 500-wd sum) 1/2/78 to** Optical Society of America, IQEC X, Suite 620, 2000 L St., N.W., Washington, DC 20036

JUN 20-22, 1978 — **Pulse Power Modulator Symp** (IEEE *et al*) Statler Hilton, Buffalo, NY **Deadline Info: (ab) 3/10/78 to** Leonard Klein, Palisades Institute for Research Services, Inc., 201 Varick St., New York, NY 10014

JUN 26-29, 1978 — **Conf. on Precision Electromagnetic Measure** (IEEE, URSI/USNC) Conf. Ctr., Ottawa, Ont. **Deadline Info: (ab & summary) 1/15/78 to** Dr. Andrew F. Dunn, Natl. Research Council, Montreal Road, Ottawa, Ont.

JUL 16-21, 1978 — **Power Engineering Society Summer Mtg.** (IEEE) Los Angeles, CA **Deadline Info: 2/1/78 to** G.A. Davis, Southern Calif. Edison Co., PO Box 800, Rosemead, CA 91770

SEP 12-14, 1978 — **AUTOTESTCON (Automatic Support Systems for Advanced Maintainability)** (IEEE) San Diego, CA **Deadline Info: 4/15/78 to** Bob Aguais, General Dynamics, Electronic Div., M.S. 7-98, PO Box 81127, San Diego, CA 92138

OCT 1-5, 1978 — **Industry Applications Society Conf.** (IEEE) Royal York Hotel, Toronto, Ont. **Deadline Info: 3/7/78 to** Harry Prevey, 4141 Yonge Street, Willowdale, Ont. M2P 1N6

OCT 9-11, 1978 — **Semiconductor Laser Conf. (6th)** (IEEE) Hyatt Regency Hotel, San Francisco, CA **Deadline Info: 6/15/78 to** T.L. Paoli, Bell Laboratories, 600 Mountain Ave., Murray Hill, NJ 07974

OCT 11-12, 1978 — **3rd Specialist Conf. on Tech. of Electroluminescent Diodes** (IEEE) Hyatt Regency Hotel, San Francisco, CA **Deadline Info: 6/15/78 to** R.N. Bhargava, Phillips Lab., Briarcliff Manor, NY 10510

NOV 7-9, 1978 **PLANS '78 (Position Location & Navigation Symp.)** (IEEE) San Diego, CA **Deadline Info: 5/15/78 to** Nelson Harnois, Cubic, PO Box 80787, San Diego, CA 92138

DEC 4-6, 1978 — **Natl. Telecommunications Conf.** (IEEE) Hyatt Hotel, Birmingham, AL **Deadline Info: 5/78 to** H.T. Uthlaut, Jr., South Central Bell, PO Box 771, Birmingham, AL 35201

Pen and Podium Recent RCA technical papers and presentations

To obtain copies of papers, check your library or contact the author or his divisional Technical Publications Administrator (listed on back cover) for a reprint. For additional assistance in locating RCA technical literature, contact RCA Technical Communications, Bldg. 204-2, Cherry Hill, N.J., extension PY-4256.

Advanced Technology Laboratories

D.A. Gandolfo| D.B. Stepps
A. Boornard| E.P. Herrmann| J.R. Tower
Gigabit recorder readout experiments with integrated photosensors—*Proc.* Electro-Optics/Laser '77 Conf. & Expo., Anaheim, CA (10/26/77)

W.F. Heagerty| H.W. Kaiser
Closed geometry CMOS/SOS structures for linear and radiation hardened applications—1977 IEEE SOS Workshop, Vail, CO (9/28/77)

R.F. Kenville
Optical video disc for high rate digital data recording—*Proc.* Electro-Optics/Laser '77 Conf. & Expo., Anaheim, CA (10/26/77)

A. Merriam
Industry support—PRIME Local Workshop, Villanova U., Phila., PA (8/24/77)

A. Merriam
Video monitor microcomputer demonstration—PRIME Local Workshop, Villanova U., Phila., PA (8/25/77)

S. Ozga
CMOS/SOS microprocessor for military applications—Seminar on Improving Utilization of Advanced IC Technology, IDA, Arlington, VA (8/9-11/77)

S.E. Ozga
CMOS/SOS processor—AIAA Computers in Aerospace Conf., Los Angeles, CA (10/31/77)

P. Ramondetta| J. Smiley
A design automated approach for complex CMOS LSI hybrid substrates—*Electronic Science*, Vol. 27 No. 11 (10/77) pp. 77-81

J. Saultz| A. Feller
Approaches to developing and utilizing LSI in military equipment—Seminar on Improving Utilization of Advanced IC Technology, IDA, Arlington, VA (8/9-11/77)

J. Schanne| B. Schaming
J. Rudnick| G. Claffie| J. Richards
A digital real time intraframe video bandwidth compression system—SPIE Symp., San Diego, CA (8/25/77)

R.D. Scott| E.W. Schlieben| T.D. Michaelis
Mechanical capacitor—*Proc.* 1977 Flywheel Technology Symp., San Francisco, CA (10/5-7/77)

Automated Systems

B.R. Clay| W.J. Hannan| M.T. Gale| K. Knop
Embossed holograms—Electro-Optics/Laser '77 Conf. & Expo., Anaheim, CA (10/26/77)

R.F. Gerenz
Data fusion—Electronics in NORAD Symp., AF Academy, Colorado Springs, CO (9/13-15/77)

M.L. Johnson
Product support—Society of Logistics Engineers (10/6/77) Wenham, MA

D.M. Priestley| R.P. Percoski
New technology automatic test system simplifies maintenance interface with ARTADS—ACFEA Seminar, Ft. Monmouth, NJ (9/15/77)

Globcom

M.E. Logiadis
International field tests of digital facsimile equipment—CCITT Study Group (11/14-18/77)

Government Communications Systems

R.Buskirk| E.J. Nossen
ECM/ECCM effects on voice transmission—*Proc.*, Intl. Telemetering Conf., Los Angeles, CA (10/18-20/77)

C. Haber| E.J. Nossen
Pseudo-random code sidelobe canceller—*Proc.*, Intl. Telemetering Conf., Los Angeles, CA (10/18-20/77)

D. Hampel| C.W. Gwinn
Polynomial array techniques in forecasting, prediction and recognition—*Proc.*, 1977 Intl. Conf. on Cybernetics & Society, Washington, DC (9/20/77)

M. Nguyen| R. Pickholtz
Bounds for the queue in loop system—Intl. Symp., Performance on Queuing System, Ithaca, NY (10/10/77)

E.J. Nossen
The Apollo VHF ranging system—*Proc.*, Intl. Telemetering Conf., Los Angeles, CA (10/18-20/77)

E.J. Nossen
Communications in a counter-measures environment—*Conf. Record,* INTELCOM '77, Atlanta, GA (10/12-14/77)

E. Nossen| C. Haber
Low cost pseudo noise modem—*Conf. Record*, INTELCOM '77, Atlanta, GA (10/12-14/77)

V. Volertas| E.J. Nossen
Phase modulation techniques for digital communication systems—*Conf. Record,* INTELCOM '77, Atlanta, GA (10/12-14/77)

Government Systems Division

J. Hilibrand
Custom CMOS LSI for military systems—Seminar on Improving Utilization of Advanced IC Technology, IDA, Arlington, VA (8/9-11/77)

Laboratories

A. Bloom| P.L.K. Hung
The effect of dye structure on order parameter in a nematic liquid crystalline host—*Molecular Crystals Liquid Crystals,* Vol. 40 (1977) pp. 213-221

I. Halta| W. Rehwald
Specific heat of $Sn_xGe_{1-x}Te$ crystals near the structural phase transition—*J. Physics,* Vol. C10, No. 12 (7/28/77) pp. 2075-81

J.I. Pankove| D.E. Carlson
Photoluminescence of hydrogenated amorphous silicon—*Appl. Physics Lett.*, Vol. 31 No. 7 (10/1/77) p. 450

S. Roth| W. Rehwald| H. Mallie
Acoustic soft modes of Nb_3Sn in high magnetic fields—*Solid State Communications*, Vol. 22 No. 3 (4/77) pp. 177-79

W. Rehwald| J.R. Sandercock| M. Rossinelli
Elastic properties of KCN and $K(CN)_{1-x}Cl_x$—*Physics Status Solidi*, Vol A42, No. 2 (8/16/77) pp. 699-705

H.S. Sommers, Jr.| H.F. Lockwood
Optical absorption coefficient of $(Al_{.42}Ga_{.58})As$—*J. Appl. Physics,* Vol. 48 No. 9 (9/77) p.4000

P.K. Weimer
Thin-film transistors in integrated circuits—present status and prospects—*Conf. Record*, Intl. Conf. on Thin- and Thick-film Devices, Augsburg, Germany (9/28-30/77) pp. 133-35

Missile and Surface Radar

J.A. Bauer
Use of chip carriers for high packaging density, high reliability, high performance products—*Proc.*, NEPCON '77 (9/77) p. 50

E. Dixon
Microwave engineering today—Natl. Science Foundation, Temple U., Phila., Pa. (9/25/77)

B.P. Gaffney| J.N. Gowdy
A symmetry relationship for "between" scaling—*IEEE Trans. on Acoustics, Speech, and Signal Processing,* Vol. ASSP-25 No. 4 (8/77)

S. Halpern
The assurance sciences—an introduction to quality control and reliability—Prentice Hall, Inc. (10/77)

V.W. Hammond| J.W. Bornholdt
Range instrumentation radar systems—Military Electronics Defense Expo '77, Wiesbaden, West Germany (9/27-29/77)

E.G. Lurcott
F^2D^2, a system management tool—Defense Systems Management Review, Vol. 1, No. 4 (Autumn 1977) pp. 19-28

V. Mangulis
An approximation for diffraction by a circular cylinder—*Microwave Journal,* Vol. 20, No. 9 (9/77) p. 72

L.W. Martinson| J.A. Lunsford
CMOS/SOS technology and its application to digital signal processing—*Proc.,* EASCON 1977, Washington, DC (9/26-28/77)

G.J. Mayer
Experimental results of a programmable analog-weight CCD convolver and some unique radar applications—Intl. Electrical, Electronics Conf. and Expo., Toronto, Ont., (9/26-28/77)

G.J. Mayer| B.P. Gaffney
Model and simulation of charge-coupled devices for signal-processing analysis—1977 Intl. Electrical, Electronics Conf. and Expo., Toronto, Ont. (9/26-28/77)

F. Reifler
The optimal orthogonal control law for maximizing terminal missile speed—SIAM, Albuquerque, NM (10/31/77)

R.J. Smith
A bit-slice module set for microcomputing—COMPCON '77 Fall, Washington, DC (9/6-9/77)

L. Weinberg
Scheduling multifunction radar systems—*Proc.,* EASCON '77, Washington, DC (9/6-9/77)

RCA Service Co.

L.E. Mertens|F.S. Replogle, Jr.
Use of point spread and beam spread functions for analysis of imaging systems in water—*J. Optical Soc. Amer.* (8/77)

R.E. Taylor| J.S. Hill
Airborne urban/suburban noise measurements at 121.5/243 MHz—*Record,* 1977 Intl. IEEE Symp. on Electromagnetic Compatibility, Seattle, WA (8/3/77)

Patents

Advanced Technology Laboratory

W.F. Heagerty| L. Dillon, Jr.
Edgeless transistor—4054894 (assigned to U.S. Government)

Avionics Systems

W.L. Ross
Multi-target tracker for tracking near co-range targets—4052721

Broadcast Systems

W.J. Derenbecher, Jr.
PAL four-frame subcarrier phase detector—4052733

P.J. Schmalz
Helical resonator—4052684

Consumer Electronics

L.A. Cochran
Hue correction apparatus controlled by chrominance saturation—4051510

L.A. Harwood
Phase control circuit suitable for use in a tint control stage of a color television system—4051519

L.A. Harwood
Video amplifier for combining luminance and chrominance signals—4051521

L.A. Harwood| E.J. Wittmann
Automatic chrominance gain control system—4054905

G.K. Sendelweck
Burst gate pulse generator—4051518

Government Communications Systems

P.J. Anzalone
Low noise amplifier—4035738 (assigned to U.S. Government)

L.P. Nahay
Solid state two-wire/four-wire converter with common battery—4053722 (assigned to U.S. Government)

Government Systems Division

E. Jellinek
Heading sensor for vehicle dead reckoning system—4055750

Laboratories

R.A. Bartolini| A. Bloom
Organic medium for thin-phase holography—4055423

J.C. Bleazey| M.A. Leedom
Stylus arm lifting/lowering apparatus for a video disc player—4053161

A. Bloom| R.A. Bartolini
Organic volume phase holographic recording medium—4049459

W.J. Burke| P. Sheng
Recording a phase hologram having reduced intermodulation distortion—4054358 (assigned to U.S. Government)

C.R. Carlson
Analog optical block processor—4045133 (assigned to U.S. Government)

A.S. Clorfeine
Bi-static radar speed sensor—4050071

A.G. Dingwall
Method of making a semiconductor device—4045250

A.G. Dingwall
Semiconductor integrated circuit device including an array of insulated gate field effect transistors—4045811

M. Ettenberg| H.F. Lockwood
Electroluminescent semiconductor device having a restricted current flow—4048627

A.M. Goodman
Capacitance meter bias protection circuit—4050018

P.E. Haferl
Switched vertical deflection system—4048544

W.E. Ham
Silicon-on-sapphire mesa transistor having doped edges—4054895

K.W. Hang
Glass frit composition for sealing window glass—4049872

G.B. Herzog
Combined controlled oscillator and frequency multiplier—4052673

R.J. Himics| N.V. Desai| E.S. Poliniak
Method of transferring a surface relief pattern from a poly(olefin sulfone) layer to a metal layer—4045318

R.J. Himics| S.O. Graham| D.L. Ross
Photosensitive copolymer on silicon support—4054454

S.T. Hsu
Complementary field effect transistor amplifier—4045747

S.P. Knight
Uhf tuning circuit utilizing a varactor diode—4048598

S.P. Knight| T.E. Molinari
Planar printed circuit board arrangement useful in the uhf portion of a television tuner—4048597

I. Ladany
Light emitting diode having a short transient response time—4049994

H.P. Lambert
Simultaneous location of areas having different conductivities—4046606

M.A. Leedom
Pickup cartridge—4049280

H.F. Lockwood| M. Ettenberg
Liquid phase epitaxial growth with interfacial temperature difference—4052252

G.S. Lozier| P.B. Branin
Method for preparing filter-coated phosphor particles—4049845

M.J. Lurie
Providing a representation of information stored in a hologram—4054357

G.H. Olsen| V.S. Ban
Methods of defining regions of crystalline material of the group III-V compounds—4053350

J.A. Rajchman
Apparatus and method for modulating a flat panel display device—4051468

A. Rosen| L.S. Napoli
Microwave frequency discriminator comprising an FET amplifier—4053841 (assigned to U.S. Government)

B.D. Rosenthal
Comparator circuit—4047059

B.D. Rosenthal
Current subtractor—4055812

B.D. Rosenthal| A.G. Dingwall
Circuit for starting current flow in current amplifier circuits—4051392

W. Rosnowski| S. Ponczak
Method of selective aluminum diffusion—4050967

R.G. Stewart
Power-on reset circuit—4045688

A.V. Tuma| J. Schiess
Frequency doubler—4052626

Z. Turski| D.D. Mawhinney
Microwave frequency discriminator comprising an FET amplifier—4053842 (assigned to U.S. Government)

P.K. Weimer
Charge transfer readout circuits—4055836

C.E. Weitzel
Method of etching sapphire utilizing sulfur hexafluoride—4052251 (assigned to U.S. Government)

C.F. Wheatley, Jr.
Adjustable gain current amplifiers—4045746

C.F. Wheatley, Jr.
Transistor amplifiers—4051441

C.F. Wheatley, Jr.
Transistor amplifiers—4055811

B.F. Williams| D.L. Staebler
W.J. Burke| W. Phillips
Crystals for recording phase holograms—4052119 (assigned to U.S. Government)

Picture Tube Division

D.E. Griesemer
Cathode-ray tube screening exposure method—4052725

H.B. Law
Method for forming a color television picture tube screen—4049451

E.M. Nekut
Reverse-printing method for producing cathode-ray-tube screen—4049452

E.S. Thall
Method for assembling a thermally-set getter spring in a CRT—4045849

SelectaVision Project

T.F. Kirschner
Stylus cleaning system for disc record player—4046384

Solid State Division

A.A. Ahmed
Current divider—4045694

A.A. Ahmed
Current-operated circuits and structures—4051391

A.A. Ahmed
Current scaling apparatus—4055774

A.A. Ahmed
Monostable switching circuit—4047057

A.A. Ahmed
Thyristor switching circuit—4047054

M. Glogolja| C.B. Leuthauser
Transient and thermal protection—4054845

L.F. Heckman, Jr.
Radio frequency coupler—4051447

J.S. Radovsky
Phase-splitter—4049977

O.H. Schade, Jr.
Ground fault interrupter apparatus—4045822

J.P. White| P.J. Kannam
High voltage semiconductor device having a novel edge contour—4047196

RCA plans Finite Element Symposium—papers invited

Finite-element computer methods provide powerful ways of solving engineering problems. These methods have been applied, for example, in determining stress distributions in satellites and tv picture tubes, natural frequency of vibration in antennas, heat flow in large electron tubes, and strength of silicon wafers. This work is presently being carried out in at least four different RCA locations.

Accordingly, a symposium is being planned to let engineers hear formal presentations, meet to discuss mutual problems, and introduce finite-element methods to those who have not yet had "hands-on" experience with them.

RCA engineers and scientists who have used finite element methods or who would like to learn about the use of these methods are invited both to attend and present papers. Publication of papers that are not proprietary is planned in the *RCA Review*.

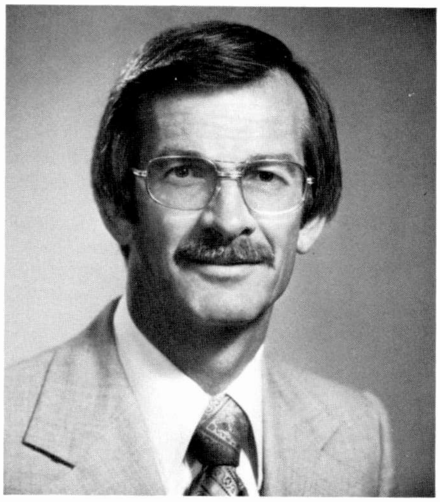
Here are the details of the conference:
- Date: **March 13 and 14, 1978**
- Place: RCA Laboratories, Princeton, N.J.
- Expression of interest and possible title of presentation by January 15, 1978
- Deadline for abstract: February 15, 1978
- Deadline for manuscripts of papers for publication: March 15, 1978

Please send abstracts/papers/expressions of interest to any one of the following committee members:

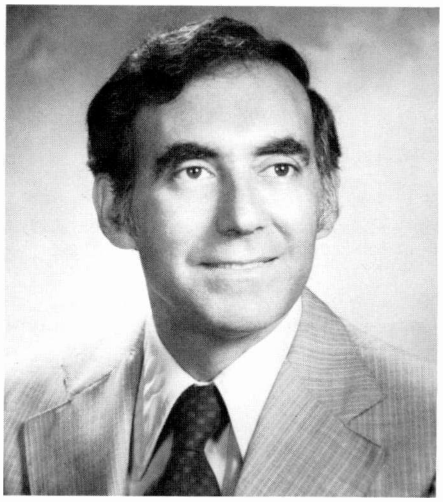
R. E. Enstrom, Chairman (RCA Laboratories, Princeton, N.J.)
R.C. Bauder (Picture Tube Division, Lancaster, Pa.)
W.W. Metzger (Astro Electronics, Princeton, N.J.)
R. Pschunder (Missile & Surface Radar, Moorestown, N.J.)
A.W. Sheffler (Astro Electronics, Princeton, N.J.)
B.P. Wang (Astro Electronics, Princeton, N.J.)

Engineering News and Highlights

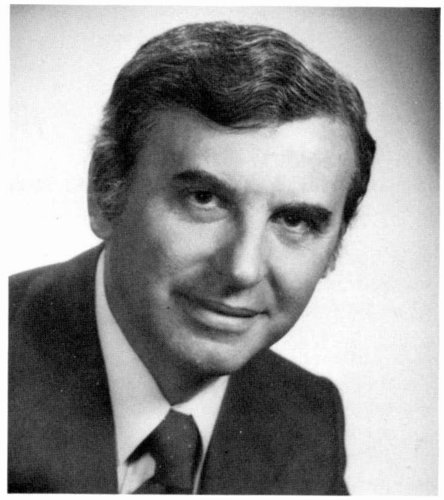
Wright, Shashoua, Ross have new jobs in GSD



Paul E. Wright was appointed Division Vice President, Engineering, for Government Systems Division, Moorestown, N.J. He is responsible for coordination of engineering activities for GSD's four business units: Astro-Electronics, Automated Systems, Government Communications Systems, and Missile and Surface Radar. For the five years preceding this promotion, Mr. Wright was Director, Advanced Technology Laboratories. Since joining RCA in 1958, he has held positions as Manager, Applied Physics and Mechanics; Manager, Advanced Mechanical Technology, and other engineering posts with the Laboratories.



Fred E. Shashoua was appointed Director, Advanced Technology Laboratories, Government Systems Division. He will manage research and development activities at ATL, Camden. Joining RCA in 1956 as an electronics engineer, Mr. Shashoua has held jobs as Leader, Recording Systems Development; Manager, Advanced Recordings and Displays; Manager, Advanced Technology Laboratory, Burlington; and most recently Manager, Electro-Optical Systems, Automated Systems.



Dr. Sidney Ross was appointed Staff Technical Advisor for Government Systems Division. He is responsible for independent research and development within the Division. He was Technical Director, Frankford Arsenal, Philadelphia, since 1968. He joined Frankford Arsenal in 1948 as a Project Engineer in the Physics and Engineering Department. Dr. Ross received the BS from Pennsylvania State University, the MS from the University of Pennsylvania and the PhD from Temple University—all in physics. He did post doctoral work at Princeton University and the University of California at Los Angeles. He is a registered professional engineer in Pennsylvania. A recipient of many government honors, Dr. Ross received the Department of the Army Outstanding Performance Award in 1965 and again in 1976. He is a member of Sigma Pi Sigma, the national physics honor society; American Institute of Physics, American Physical Society, Scientific Research Society of America and the Optical Society of America.

Licensed engineers

When you receive a professional license, send your name, PE number (and state in which registered), RCA division, location, and telephone number to: *RCA Engineer*, Bldg. 204-2, RCA, Cherry Hill, N.J. New listings (and corrections or changes to previous listings) will be published in each issue.

RCA American Communications, Inc.

Paul W. DeBaylo, Piscataway, N.J.; Cal.-QU2047.

Astro-Electronics

Albert L. Goldsmith, Princeton, N.J.; Cal.-QU2379.

Government Communications Systems

Harold A. Brill, Camden, N.J.; NJ-24489.

RCA Records

Charles A. Weaver, Indianapolis, Ind.; IN-17205.

Solid State Division

Cory C. Williams, Findlay, Ohio; IN-14914; OH-014667.

Ernest D. Scaran, Mountaintop, Pa.; PA-26505-E.

Salvadore P. Barlett, Mountaintop, Pa.; PA-26487-E.

Degrees granted

Mobile Communications Systems

William G. Stewig—MBA, University of Pittsburgh.

Solid State Division

Wallace D. Williams—MS, Physics; Rutgers University.

Nine technical excellence award winners at Moorestown

Maurice Breese—for technical creativity and leadership in developing a diode phase shifter concept for advanced array applications.

Girard Goldkrantz—for personal initiative and technical competence demonstrated in design of the two AN/SPY-1A Moving Target Indicator cabinets.

Doug Perham—for creative and resourceful design effort in the successful modification of the Haystack Long-Range Imaging Radar (LRIR).

Frank Reifler—for outstanding achievement in the design of filters and related algorithms for AEGIS, and for important contributions to filter theory.

Bob Sharp—for his timely and imaginative application of high-level functional analysis in support of design of the AEGIS Ship Combat Information Center.

Vic Stachejko—for his conceptual creativity in the development of a microwave phase modulator in integrated circuit form, exhibiting unprecedented accuracy over an octave bandwidth.

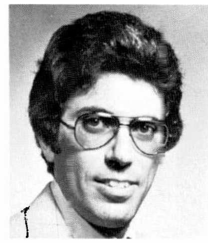
Three key members of the AEGIS AN/SPY-1A Signal Processor test team were honored for their achievements in the successful test and qualification of this very complex system in less than six months (less than one-half the time taken for the EDM-1 Signal Processor):

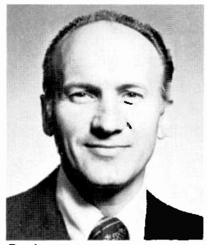
George Oakes—for his special contributions as Senior Project Engineer during the checkout and performance qualification testing.

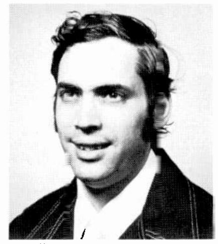
Bob Peterson—for his special contributions as the program's Systems Test Engineer.

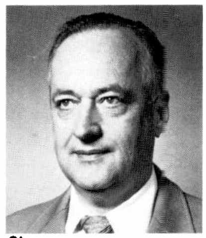
Harry Ulrich—for his technical leadership and direction of the engineering test team responsible for qualification of the Signal Processor.


Breese

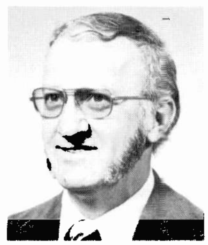

Goldkrantz


Perham

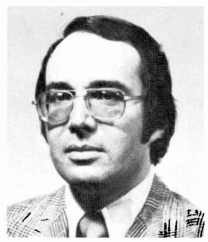

Reifler


Sharp


Stachejko


Oakes


Peterson


Ulrich

Four cited at Astro-Electronics

A new method for producing welded-wire circuit-board documentation won a Technical Excellence Team Award for four engineers at Astro-Electronics. The new technique developed by award winners **Tom Murphy, Bill Mulrooney, Doug Milke,** and **Joe Scaven** has proven to be more efficient and accurate than the previous manual method system.


Murphy


Mulrooney


Milke


Scaven

Ten win TE award at Automated Systems

Test system development work led to a team award for ten engineers at Automated Systems in Burlington, Mass. In the photo, left to right, are **H.J. Woll,** Div. V.P. and General Manager; team members **B. Ballard, R.M. Carner** (seated), **D.L. Boudreau, C.F. Sullivan, M.F. LeVarn, J.P. Godfrey** (seated), and **M.H. Strong;** Project Manager, **W.R. Wadden;** team members **S.P. Patrakis** (seated) and **J.H. O'Connell;** Manager Data Systems Development, **A.F. Dirsa;** Chief Engineer, **E.M. Stockton;** team member **J.M. Goode** (seated); and Manager of Command and Control Programs, **E.O. Seaborn.**

Obituaries

Dudley M. Cottler, Staff Technical Advisor, Government Engineering, GSD, died October 10, 1977.

He joined RCA in 1956 and held several engineering management positions involving the design, development, production, and testing of radar systems. He was Chief Engineer of the Missile and Surface Radar Division from 1967 to 1974. During that time the division made important advances in radar and systems technology, ranging from such major systems developments as AEGIS and AN/FPS-95 to such critical concept developments as ultra-high-speed digital design for advanced data/signal processing systems. In his most recent job, Mr. Cottler was responsible for the Independent Research and Development Program for all of the Government Systems Division's government contracts—administering the fields of investigation and the allocation of funds for the program.

W.Walter Watts, a former senior officer and Director of RCA, died November 15. He retired from RCA as an Executive Vice President in May 1970, but continued to serve on the company's Board of Directors for another year.

Mr. Watts joined RCA in 1945 after wartime service as a Colonel and Commanding Officer of the Signal Corps Distribution Agency. He was elected a Vice President of RCA in 1946 and Executive Vice President, Electronic Products, in 1954. He became Executive Vice President, Electronic Components, in 1955, and Group Executive Vice President in 1958. He was Chairman of the RCA Sales Corporation and the the RCA Victor Distributing Corp. from 1960-64. He became Senior Executive Vice President, Defense and Commercial Systems, in 1968.

Recent books by RCA authors

The Assurance Sciences—
An Introduction to Quality Control and Reliability

Sigmund Halpern
Published by Prentice-Hall Inc.
[448 pp, $16.95]

Author Halpern joined RCA Camden in 1951 as a design engineer. He later transferred to the reliability department at Astro Electronics, where his responsibilities as engineering leader involved many reliability tasks on space programs. Since 1970 he has been associated with MSR's. Technical Assurance Department. He provided us with the following description his book.

This book is designed to fill a void in most of today's engineering curricula—the nearly total absence of courses in the assurance sciences. The lack of attention paid to the fields of quality control, reliability, maintainability,and integrated logistic engineering often becomes evident when a graduate is hired by an aerospace or defense contracting firm. Commercial manufacturers are also becoming increasingly interested in the potential benefits that more organized reliability and maintainability disciplines could offer them.

Because the book is a comprehensive introductory text that develops a working knowledge of the assurance sciences without prior experience, it is ideally suited for use in engineering colleges and technical institutes. A helpful feature is the inclusion of pertinent portions of government and military specifications and standards and the demonstration of their use in many of the practical problems solved.

The book should be equally valuable as an on-the-job training tool for engineers, managers, and technicians exposed to these fields.

Vollmer is President, Philadelphia Chapter NSIA

Dr. James Vollmer, Division Vice President and General Manager, Government Systems Division, was elected President of the Philadelphia Chapter, National Security Industrial Association. NSIA is a nationwide organization of industry representatives advising government on technological matters concerning national security.

Rajchman receives Pender Award

Dr. Jan A. Rajchman, retired Staff Vice President, Information Sciences, RCA Laboratories, received the University of Pennsylvania's Pender Award for distinguished engineering contributions. The award was presented to him on October 28 at the annual dinner meeting of Penn's Engineering Alumni Society.

Promotions

Consumer Electronics

Paul L. Vos from Junior Member, Engineering Staff, to Regional Training Manager.

Solid State Division

Jorgan F. Nielsen, from Member, Technical Staff, to Leader, Technical Staff.

Picture Tube Division

Walter R. Rysz from Member, Technical Staff, to Manager, Production Engineering.

Missile and Surface Radar

Lee Upton, Jr. from Senior Member, Engineering Staff, to Unit Manager, Systems Engineering.

Perry Willis from Unit Manager, Engineering Systems Projects, to Manager, Test Documentation.

Stanley Stern from Unit Manager, Systems Engineering, to Manager, C&D Projection.

Gordon Caldwell from Unit Manager, Systems Engineering, to Manager, Facilities.

Harry Irion from Senior Member, Engineering Staff, to Unit Manager, Systems Engineering.

Kent Ringo from Senior Member, Engineering Staff, to Unit Manager, Engineering Systems Projects.

Roy Sewell from Senior Member, Engineering Staff, to Unit Manager, Engineering Systems Projects.

Herman Siegel from Senior Member, Engineering Staff, to Unit Manager, Engineering Systems Projects.

Charles Smith from Principal Member, Engineering Staff, to Unit Manager, Systems Engineering.

John Scarrow from Senior Member, Engineering Systems Projects, to Unit Manager, Engineering Systems Projects.

James Sprinkle from Senior Member, Engineering Systems Projects, to Unit Manager, Engineering Systems Projects.

Robert Cower from Senior Member, Engineering Staff, to Unit Manager, Engineering Systems Projects.

Ralph D. Rippey from Senior Member, Engineering Staff, to Unit Manager, Design and Development Engineers.

George L. Maas from Senior Member, Engineering Staff, to Unit Manager, Engineering Systems Projects.

Staff announcements

President and Chief Executive Officer

Edgar H. Griffiths has announced that **Paul Potashner,** Group Vice President, will be responsible for:

- Banquet Foods Corporation
- Coronet Industries, Inc.
- Oriel Foods Group
- Random House, Inc.
- RCA Records Division

Distributor and Special Products Division

Julius Koppelman, Group Executive Vice President, has appointed **James J. Badaracco** Division Vice President and General Manager, Distributor and Special Products Division.

Commercial Communications Systems Division

Neil Vander Dussen, Division Vice President and General Manager, appointed **Henry H. Klerx** Manager, Business Planning, a new CCSD staff position.

Neil Vander Dussen appointed **Arthur J. Barrett** Division Vice President, Manufacturing.

Mobile Communications Systems

Lee F. Crowley has been appointed Manager, Engineering and Technical Services, a new position in the Mobile Communications Systems organization, reporting to **Joseph P. Ulasewicz,** Division Vice President and General Manager. In addition, **George R. Kamerer** was promoted to Manager, Engineering.

Solid State Division

Carl R. Turner, Division Vice President, Solid State Power Devices, has announced the organization of Solid State Power Devices as follows: **Angelo D. Checki,** Manager, Operations Planning and Administration—Power; **Ralph S. Hartz,** Director, Power Engineering; **John E. Mainzer,** Director, Power Manufacturing Operations; **Robert E. O'Brien,** Manager, Technology Transfer Program; and **Donald Watson,** Director, Product Marketing—Power.

Ralph S. Hartz, Director, Power Engineering, announced the organization of Power Engineering as follows: **Donald E. Burke,** Manager, Device Development Engineering; **Edward A. Czeck,** Manager, Type Engineering; **Robert J. Satriano,** Manager, Process Equipment and Package Engineering; and **Wallace D. Williams,** Manager, Test Development and Device Evaluation Engineering.

Wallace D. Williams, Manager, Test Development and Device Evaluation Engineering announced the organization of Test Development and Device Evaluation Engineering as follows: **Keith E. Loufborrow,** Leader, Technical Staff—Test Equipment Engineering; and **Wallace D. Williams,** Acting Leader—Test and Evaluation Engineering.

Dale M. Baugher, Manager, Power Applications—Power announced the organization of Applications Engineering—Power as follows: **Wilfred P. Bennett,** Leader, Technical Staff—Automotive; **John Cadra,** Administrator, Market Planning—Commercial Coordination; **Leonard M. Gibbons,** Leader, Technical Staff—Industrial/Computer; **Thomas C. McNulty,** Leader, Technical Staff—Applicance, Audio and T.V.; and **William H. Schilp,** Leader, Technical Staff—Hi Rel, Communications, Telecom and R.F.

Thomas T. Lewis, Director, Electro-Optics Operations, appointed **Carl L. Rintz** Manager, Electro-Optics Market Planning.

Richard L. Sanquini, Director, Bipolar IC Operations, announced the organization of Bipolar IC Operations as follows: **Heshmat Khajezadeh,** Manager, Engineering—Bipolar IC; **Seymour Reich,** Manager, Bipolar IC Marketing; and **John A. Schramm,** Manager, Manufacturing—Bipolar IC.

Norman C. Turner, Director, MOS Engineering, announced the organization of MOS Engineering as follows: **Henry S. Miller,** Manager, MOS Reliability Programs; **Eugene M. Reiss,** Manager, MOS Hi-Reliability Engineering; **George J. Waas,** Manager, Engineering Support; and **Alexander W. Young,** Manager, MOS Circuit Design.

Peter J. Jones, Director, Product Marketing—MOS, announced the organization of Product Marketing, MOS as follows: **Andrew J. Bosso,** Manager, Product Marketing—MOS Distributor; **Michael V. D'Agostino,** Manager, Product Marketing—MOS Major Programs; **Jack Handen,** Manager, Product Marketing—MOS Hi-Reliability Products; **Peter J. Jones,** Acting Manager, Product Marketing—MOS OEM; and **Henry L. Pujol,** Manager, Applications Engineering—MOS.

Robert O. Winder, Director, MOS Systems, announced the organization of MOS Systems as follows: **Donald R. Carley,** Manager, Custom Systems Designs; **Edwin M. Fulcher,** Leader, Hardware; **Julius Litus, Jr.,** Manager, Support Systems; **Larry A. Solomon,** Leader, Software; and **Robert O. Winder,** Acting Manager, New Products.

David S. Jacobson, Manager, Photomask Operations, announced the organization of Photomask Operations as follows: **Robert Nestel,** Leader, Technical Staff—Photomask Tooling; **Robert L. Rhodes,** Manager, Photomask Engineering & Quality Assurance; and **Evan P. Zlock,** Manager, Photomask Production.

Henry L. Pujol, Manager, Applications Engineering—MOS, announced the organization of Applications Engineering—MOS as follows: **Richard E. Funk,** Leader—Product Performance Engineering; **Al A. Key,** Leader—Memories/Microprocessors; and **Henry L. Pujol,** Acting Leader—Logic Timekeeping.

Government Systems Division

Dr. James Vollmer, Division Vice President and General Manager, has appointed **Paul E. Wright** Division Vice President, Engineering.

Paul E. Wright appointed **Fred E. Shashoua** Director, Advanced Technology Laboratories.

Paul E. Wright appointed **Dr. Sidney Ross** Staff Technical Advisor.

PRICE Systems

Frank R. Frieman, Director, has appointed **W. Kenneth Witzgall** Manager, Technical Operations, and **Dr. Robert E. Park** Manager, Advanced Development.

Automated Systems

Dr. Harry J. Woll, Division Vice President and General Manager, has appointed **Emmett O. Seaborn, Jr.** Manager, Command and Control Programs.

RCA Service Company

Joseph F. Murray, Division Vice President, Government Services, has appointed **Robert S. Maloney, Jr.** Division Vice President of Navy Services and **Artemus W. Wren, Jr.** Division Vice President of Air Force/Army Services.

RCA Global Communications, Inc.

Eugene F. Murphy, President, announced the organization of RCA Global Communications, Inc. as follows: **Robert J. Angliss,** Executive Vice President, Switched Services; **Leonard W. Tuft,** Vice President, Leased Facilities; **Donald R. Stackhouse,** Vice President, Operations and Engineering; **Thomas J. Brady,** Vice President, RCA Globcom Systems, Inc.; **James C. Hepburn,** Vice President and Technical Director; **Robert Luongo,** Vice President, Finance; **Francis J.H. DeRosa,** Vice President and General Counsel, Law & Regulatory Affairs; **Robert C. McHenry,** Vice President, Industrial Relations; and **George A. Shawy,** Vice President, Corporate Affairs.

Donald R. Stackhouse, Vice President, Operations & Engineering, announced the organization of Operations and Engineering as follows: **Eugene M. Gaetano,** Vice President, Pacific Operations; **Notis M. Kotsolios,** Director, New York/Kingsbridge Operations; **George M. Weisberg,** Director, Operations Services Planning & Control; **Robert T. Lundquist,** Manager, Atlantic Operations; **Alexander A. Avanessians,** Staff Engineer; **Louis P. Correard,** Manager, Standards & Documentation; **James R. McDonald,** Manager, Systems Engineering; **Solomon J. Nahum,** Manager, Construction Engineering; **John P. Shields,** Manager, Project Engineering; **Roy B. Andersen,** Manager, Administration & Planning; and **John P. Feeley,** General Manager, Philippines.

Consumer Electronics

Dr. Jay J. Brandinger, Division Vice President, Engineering, appointed **Dr. J. Peter Bingham** Chief Engineer, New Products Laboratory.

Dr. D. Joseph Donahue, Division Vice President, Operations, appointed **Charles A. Quinn** Division Vice President, Materials.

Patent Operations

W. Brinton Yorks has joined RCA Patent Operations at the David Sarnoff Research Center in Princeton, N.J.

RCA Laboratories

Joseph H. Scott, Jr. Director, Integrated Circuit Technology, appointed **Dr. David E. O'Connor** Head of the Solid State Device Technology Group.

Letters

Our thanks to all of you who wrote to comment on our last issue. We don't normally publish letters, but we did ask readers to respond to the anti-technology attitude reported by Harry Kleinberg in his article "Zen, existentialism, and engineering." Part of those responses are given below.

...I found H. Kleinberg's article in the Aug/Sep 1977 RCA Engineer very interesting. This article gives engineers credit for being people with interests outside of Engineering.

I believe that an anti-technology attitude does exist but that it is much more prevalent in the non-technical world. People without technical backgrounds or no interest in things technical do not understand why or how our mechanical and electronic marvels work. They find themselves in an uncomfortable position of having to depend upon things that they have no hope of understanding. When something goes wrong, they must depend upon others to make them work again. This feeling of helplessness, I feel, gives rise to a negative attitude about the technology that benefits all of us so greatly. Technical people, on the other hand, feel more comfortable in this same environment.

F.E. Korzekwa
Consumer Electronics

...I am pleased that the article brought Pirsig's brilliant "Zen and the Art of Motorcycle Maintenance" to the attention of Engineer readers. I found it one of the more exciting books of recent years. Florman's book I haven't read, but will look it up.

I have long been interested in philosophical matters, and concur that Pirsig's treatment of the classical and romantic themes is well done.

There are correspondences in the spectrum of scientist/engineer and artist/craftsman. In each, there are intuitive leaps to new discoveries that are not logical extensions of given knowledge. There is skill to express a discovery in a product. There are limitations of media and time and money to work within. There are local customs to slow innovation (we must conform to our standards, artistic or engineering!).

Codification of discovery into standard practice is necessary to teach others. What is lost, tragically so, is fun and absorption of the act of creation where a person is most alive. Technical papers are usually devoid of the excitement and textbooks are worse, giving the student the cut-and-dried results only.

A survey of science given to a liberal arts student is as dead as a history of art or music appreciation course to an engineer. Unfortunately, those who give these courses are not creative workers in either field.

When the "public" is given desiccated "science" in school and lifeless "art" via a technical medium, and has no way to participate, there will be misunderstanding.

There are indications that the schism of Classical and Romantic, Art and Science, is healing. People who grow up with computers as toys will not be awed by them, any more than by automobiles. Mechanistic science has driven itself into the realization that the observer cannot separate himself from the observed. Large scale technology faces the stubborn fact that earth is a closed system. Artists are beginning to use television technology as a new medium of expression. Pierre Boulez founded a new laboratory for electronic music in Paris.

We are, perhaps, in a classical situation where extreme polarization precedes a new synthesis.

The path of progress is not backward but forward to a new level of sophisticated technology that will be more expressive to human creative impulses.

Thank you again for a most stimulating article.

R.M. Carrell
Laboratories

...I read the article on Zen and engineering and was surprised to find out about the attitudes expressed. I retired about two years ago from a job I enjoyed very much. But retirement is even better. In general, my relationships with other people in the community were wonderful. I should say communities because I lived in four locations from Maine to Florida in the last 6 years. In each, we have encountered a "caring and sharing" group of people that have made life happy. It may be that we expect to have nice neighbors and friends and therefore do have them. No, the fact that I am or was an engineer never seemed to be a detriment in people to people relationships.

Eugene A. Mechler
ex-MSR

Address correspondence to Editor, *RCA Engineer*, Bldg. 204-2, Cherry Hill, N.J. 08101.

Editorial Representatives

Contact your Editorial Representative, at the extensions listed here, to schedule technical papers and announce your professional activities.

Commercial Communications Systems Division

Broadcast Systems

BILL SEPICH* Camden, N.J. Ext. PC-2156
KRISHNA PRABA Gibbsboro, N.J. Ext. PC-3605
ANDREW BILLIE Meadow Lands, Pa. Ext. 6231

Mobile Communications Systems

FRED BARTON* Meadow Lands, Pa. Ext. 6428

Avionics Systems

STEWART METCHETTE* Van Nuys, Cal. Ext. 3806
JOHN McDONOUGH Van Nuys, Cal. Ext. 3353

Government Systems Division

Astro-Electronics

ED GOLDBERG* Hightstown, N.J. Ext. 2544

Automated Systems

KEN PALM* Burlington, Mass. Ext. 3797
AL SKAVICUS Burlington, Mass. Ext. 2582
LARRY SMITH Burlington, Mass. Ext. 2010

Government Communications Systems

DAN TANNENBAUM* Camden, N.J. Ext. PC-5410
HARRY KETCHAM Camden, N.J. Ext. PC-3913

Government Engineering

MERLE PIETZ* Camden, N.J. Ext. PC-5857

Missile and Surface Radar

DON HIGGS* Moorestown, N.J. Ext. PM-2836
JACK FRIEDMAN Moorestown, N.J. Ext. PM-2112

Solid State Division

JOHN SCHOEN* Somerville, N.J. Ext. 6467

Power Devices

HAROLD RONAN Mountaintop, Pa. Ext. 633
SY SILVERSTEIN Somerville, N.J. Ext. 6168

Integrated Circuits

FRED FOERSTER Somerville, N.J. Ext. 7452
JOHN YOUNG Findlay, Ohio Ext. 307

Electro-Optics and Devices

RALPH ENGSTROM Lancaster, Pa. Ext. 2503

Consumer Electronics

CLYDE HOYT* Indianapolis, Ind. Ext. VH-2462
RON BUTH Indianapolis, Ind. Ext. VH-4393
PAUL CROOKSHANKS Indianapolis, Ind. Ext. VH-2849

SelectaVision Project

FRANCIS HOLT Indianapolis, Ind. Ext. VR-3235

RCA Service Company

JOE STEOGER* Cherry Hill, N.J. Ext. PY-5547
RAY MacWILLIAMS Cherry Hill, N.J. Ext. PY-5986
DICK DOMBROSKY Cherry Hill, N.J. PY-4414

Distributor and Special Products Division

CHARLES REARICK* Deptford, N.J. Ext. PT-513

Picture Tube Division

ED MADENFORD* Lancaster, Pa. Ext. 3657
NICK MEENA Circleville, Ohio Ext. 228
JACK NUBANI Scranton, Pa. Ext. 499
J.R. REECE Marion, Ind. Ext. 566

Alascom

PETE WEST* Anchorage, Alaska Ext. 0611

Americom

MAUCIE MILLER* Kingsbridge Campus, N.J. Ext. 4122

Globcom

WALT LEIS* New York, N.Y. Ext. 3089

RCA Records

JOSEPH WELLS* Indianapolis, Ind. Ext. VT-5507

NBC

BILL HOWARD* New York, N.Y. Ext. 4385

Patent Operations

JOSEPH TRIPOLI Princeton, N.J. Ext. 2491

Electronic Industrial Engineering

JOHN OVNICK* N. Hollywood, Cal. Ext. 241

Research and Engineering

Corporate Engineering

HANS JENNY* Cherry Hill, N.J. Ext. PY-4251

Laboratories

CHET SALL* Princeton, N.J. Ext. 2321
LESLIE ADAMS Somerville, N.J. Ext. 7357

*Technical Publications Administrator, responsible for review and approval of papers and presentations.

RCA Engineer

A technical journal published by Corporate Technical Communications
"by and for the RCA Engineer"

Printed in USA

Form No RE-23-3